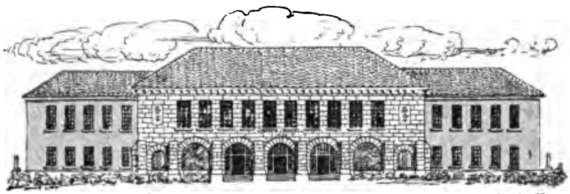


MANUAL

OF

EXPERIMENTAL BOTANY

BY

FRANK OWEN PAYNE, M.Sc.

ASSISTANT IN BIOLOGY, HIGH SCHOOL OF COMMERCE
NEW YORK

NEW YORK ·:· CINCINNATI ·:· CHICAGO
AMERICAN BOOK COMPANY

PAYNE'S BOTANY.

W. P. I

PREFACE

There is something in an experiment which appeals to the mind of the young. The innate desire to find out what is in a toy, how it works, and why various things happen, is largely responsible for this.

Chemistry and physics owe their great popularity to the fact that they have been taught by experiment. Zoölogy and botany have always been less popular because they have often been taught without experimentation.

In the days when morphology was the *summum bonum* of botanical study, there could be small room for experiment. But in these later years, when the science has been taught more along physiological lines, the use of experiment has come into more general vogue.

It is the purpose of this little book to teach botany by experiment. Plants yield themselves very readily to experiment. Being alive, they respond to all external influences most admirably, and there is no reason why such work with plants should not prove as interesting and as useful as similar exercises with levers, lenses, vibrating pendulums, and cords.

It is hoped that something may be found in this book which will remedy the inadequacy which exists in the laboratory instruction of many schools.

The work is not entirely physiological in character, but it has been thought wise to present the morphological part also in the form of experiments.

In a number of places, several experiments have been introduced to demonstrate the same truth. It is not intended, however, that all such exercises be undertaken by the same class in any one term. They are offered so that the courses from term to term can be varied, using alternative experiments.

This gives variety to the work and will make the use of old laboratory notebooks less likely.

It is also expedient often to assign for home experiment such exercises as are omitted in school. Field work should be undertaken wherever possible; but as real field work is out of the question in large cities, much reference work can be done, and a certain amount of it ought to be required.

Reference work will include the looking up of topics in libraries, and visits to museums and parks.

Written reports on assigned topics should be expected. A certain number of common plants should be known by name. This can be accomplished by requiring pupils to bring in specimens. These collections may be arranged for exhibition where all may see them and learn to recognize them.

Walks about streets and parks to identify trees and shrubs should be made from time to time, and their leaves should be collected as a means of recognizing them. The same method is recommended for ferns and garden flowers.

If the boy or girl who studies this book comes to realize that plants are *alive* as *we are alive*, — that they eat, digest, grow, and reproduce their kind as truly as we perform these functions; that they respond to outside influences as *we* do; that they are in a way our brothers; that they are necessary to us and we to them, — my object will be fulfilled.

To Dr. Walter Hollis Eddy, of the High School of Commerce, New York, for his many helpful suggestions of material and method of presentation; to Mr. Frederick L. Holtz of the Training School for Teachers, Brooklyn, who has read the

manuscript and has given it most careful criticism; and to my colleagues in the High School of Commerce, Messrs. Matthewson, Barbour, A. H. Lewis, Sprague, and Hahn, who have rendered substantial assistance in the preparation of this book, — I desire to express my sincerest thanks.

The following texts have been freely consulted: Bailey, *Principles of Agriculture, Plant Breeding,* and *Botany;* The Cornell University Bulletins; Osterhaut, *Experiments with Plants;* Percival, *Agricultural Botany;* United States Department of Agriculture Bulletins, and the botanical textbooks of Andrews, Atkinson, Bergen, Coulter, Barnes, and Cowles, Dana, Goff and Mayne, Goodale, Gray, Hunter, Leavitt, and Sharpe.

CONTENTS

EXPERIMENTAL BOTANY

I. PRELIMINARY EXPERIMENTS

What is an Experiment?

At the outset it may be well to consider what an experiment is. An experiment is often called *a question asked of nature;* really it is a trial or test, made to learn some fact of nature. For example, it is desired to know whether some particular substance will burn or will dissolve.

To make the experiments it is necessary to have certain accessory things called apparatus. In the first case, a match or lighted candle would be the apparatus. In the second case, the apparatus would be water or some other liquid, a funnel, filter paper, and an evaporating dish.

The result of trying to ignite the substance or of shaking it in the liquid will be nature's answer to the questions we have put to her, and thus the conclusion or interpretation follows; that is, this substance is or is not inflammable or it is or is not soluble. In recording an experiment let the following order be observed: —

(1) **Object.** — A statement of what is to be found out.

(2) **Apparatus.** — Names of articles used in making the experiment and drawings of them where possible.

(3) **Method and Results.** — A full statement of what was done step by step, with result of each step.

(4) **Conclusion.** — The interpretation of the results.

1. OXYGEN

Object. — *To prepare oxygen and to learn some of its properties.*

Apparatus. — An ignition tube, a small portion of red oxide of mercury, a Bunsen burner, and a splinter of pine.

Method. — Place the mercuric oxide in the ignition tube and heat it in the flame as in Figure 1. Note any change of color. What collects on the inside of the tube? How do you recognize this substance? Remove some and examine it. Plunge a charred splinter into the upper end of the tube, being sure that there is a glowing spark on the end of the splinter. What happens? Repeat the experiment several times. What must there be coming from the oxide besides what collects on the tube?

FIG. 1. — Preparing oxygen.

This is oxygen. What color or other properties has this gas? What two substances came from the oxide?

Conclusion. — Oxygen is ——, ——, ——, and supports combustion.

Note. — An alcohol lamp will seldom give sufficient heat to produce oxygen gas in any considerable quantity. In schools which

are not supplied with gas, a gasoline stove or a kerosene vapor stove can be used for experiments where considerable heat is required.

An ignition tube is better than a test tube, since it resists the heat. Test tubes in this experiment will often melt, and the oxide will escape through a hole in the bottom.

Definitions. — An element is a simple substance. It cannot be separated into any other substances.

A compound is a substance that is composed of two or more elements chemically combined. It can be separated into its elements.

In Experiment 1 the mercuric oxide is a compound consisting of oxygen and mercury. By heating we separated this compound into the elements oxygen and mercury.

This process of separating a compound into its elements is called *analysis*.

2. CARBON

Object. — *To learn some of the properties of the element carbon.*

Apparatus. — Charcoal, coal, coke, gas carbon, graphite, soot (a diamond may be shown). A lamp, test tube, and a small quantity of limewater.

Method. — Examine the various forms of carbon, but confine the experiments to charcoal. Determine the color, taste, smell, softness, brittleness, etc., of charcoal. Notice its structure. What does this reveal as to its source? Pulverize a little and shake it up in water. Is it lighter or heavier than water? Does it dissolve in water?

Hold a slender piece of charcoal in the lamp flame. What occurs? Describe the color of the flame. Does it give

off smoke? If so, its color and amount. Describe the ash, its color, and amount.

Put a small quantity of limewater in a test tube and shake it. Does any change occur? Now ignite the charcoal stick, and while it is glowing red-hot plunge it into the tube of limewater, but *not* down into the limewater. Withdraw the charcoal, and holding the thumb over the mouth of the tube, shake it. What change takes place? *This is the test for carbon dioxide.*

Through a straw or piece of glass tube, breathe into a tube of fresh limewater, letting the breath bubble through the liquid. What is the result?

Conclusion. — State properties of carbon. What forms when it burns? How is the presence of carbon dioxide detected? What proof that it is contained in our breath?

Note. — Limewater is made by placing a considerable quantity of water on slacked lime, shaking it well, and allowing it to settle. The clear liquid on top is limewater.

Definition. — Combining two or more elements to form a compound is called *synthesis.*

In burning charcoal, the element carbon united with the element oxygen in the air to make the compound carbon dioxide.

Changes like these are known as chemical changes because the original substances lose their properties and new substances are formed having new properties.

Thus the blackness, brittleness, etc., of the carbon disappeared and the different properties of carbon dioxide appeared.

Query. — In what respects does the experiment with limewater demonstrate a chemical change?

3. CARBON DIOXIDE

Object. — *To learn some characteristic properties of carbon dioxide.*

Apparatus. —A flask fitted up as in Figure 2, some broken marble, two wide-mouth bottles, a little hydrochloric acid, and the apparatus used in Experiment 2.

Method. — Place the broken marble in the flask, close it with the rubber stopper, and add the hydrochloric acid. Note the result. Collect some of the gas in a wide-mouth bottle and test it with limewater. Result? Plunge a burning stick into the bottle of carbon dioxide. Result? Select two wide-mouth bottles of equal size. Test each with limewater. Fill *one* jar with carbon dioxide and leave the other full of air. Now invert the jar full of carbon dioxide over the other. After a few moments test the contents of each bottle. Which one now contains the carbon dioxide?

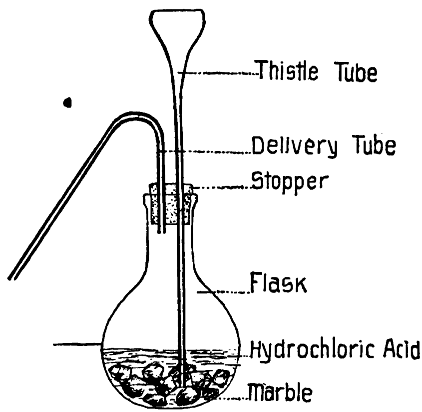


FIG. 2. — Preparing carbon dioxide.

What does this show as to the weight of this substance as compared with the air?

Let carbon dioxide bubble through a test tube of pure water for a few minutes. Taste of the water. What peculiarity has the taste?

Conclusion. — State briefly what you have learned about

carbon dioxide, giving its color, taste, smell, test, weight, and effect on burning.

Note. — The weight of carbon dioxide and its power to put out fire are well shown by filling a large wide-mouth bottle with the gas and then pouring it into an inclined trough in the bottom of which several short bits of lighted candle have been placed. The gas will flow down, and, as it meets the candles, will extinguish them one by one.

Another device may be made by placing bottles of equal weight in opposite pans of an ordinary balance. When they are exactly counterpoised, hold the delivery tube of a flask over one of the bottles, and the greater weight of the carbon dioxide will immediately cause it to sink.

Query. — What causes limewater to become covered with a scum of white substance whenever it is exposed for some time to the air?

What are some of the sources of carbon dioxide in the atmosphere? Explain the construction of a chemical fire extinguisher. On what properties of carbon dioxide does it depend?

Before going down into a deep well, how would you test the air to find out whether there is carbon dioxide present? If present, how can it be removed before you go down into the well?

Why are the laws so strict regarding ventilation of schools?

4. HYDROGEN

Object. — *To prepare hydrogen and to learn some of its properties.*

Apparatus. — Some granulated zinc or zinc scraps, dilute sulphuric acid (1 part acid poured into 5 parts of water), test tubes, Argand lamp chimney, and a flask fitted as in Figure 3.

Method. — Place the zinc in the flask (*a*), adjust the stopper (*c*), and add the weak sulphuric acid through the thistle tube (*b*). Note the result. Hold an inverted test tube over the delivery tube (*f*) and remove it, keeping it inverted. Touch a match to the open end. Result?

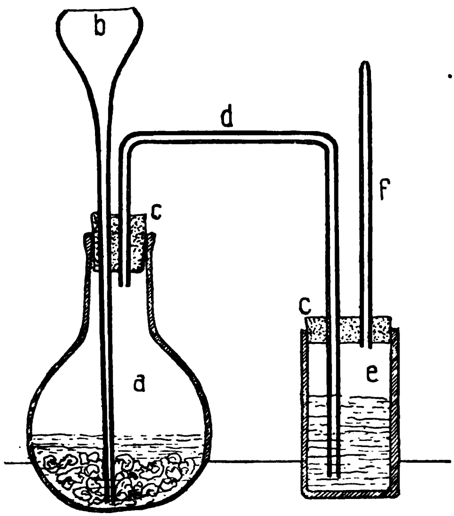


FIG. 3. — Preparing hydrogen.

Repeat the experiment several times. When you are sure that there is no air left in the flask, touch a match to the end of the delivery tube. It is well to shield the face when doing this with a fan or piece of pasteboard.

Note the color of the flame of burning hydrogen.

Hold a bit of wire in the hydrogen flame. Note the heat. Hold a piece of cold earthen plate over the hydrogen flame. What forms on the plate?

Now place an Argand lamp chimney over the burning hydrogen flame and move it slowly down. What happens? Try tubes of various sizes over the flame.

Conclusion. — Mention some properties of hydrogen. What substance forms when hydrogen burns?

Note. — If a bit of pipe stem or a platinum tip is used, the hydrogen flame will be found to be *colorless*. The yellow color seen when glass tips are used is due to the sodium in the glass.

With students it is always safest to interpose a wash bottle (*e*) between the generator and the flame so as to prevent damage in case of an explosion. If potassium permanganate is put in the wash bottle, impurities will be removed.

5. NITROGEN

Object. — *To learn something of the preparation and properties of nitrogen, and the composition of air.*

Apparatus. — A small piece of phosphorus, forceps, a cork float, a large vessel of water, a bell jar, a support for the bell jar, and several wide-mouth bottles.

Method. — Place a crumb of phosphorus upon the cork float, using the forceps for handling it. Dry it with a piece of blotting paper, but *under no circumstances let it touch the skin.*

Let it ignite spontaneously if there is time. Otherwise, ignite it with a burning splinter, and immediately invert the bell jar over it.

Note the color of the flame and smoke, the behavior of the water, and the height to which it rises in the bell jar. Why does it rise only about $\frac{1}{5}$ the height of the jar? What has been consumed? How much oxygen must there be in a given amount of air? What becomes of the white fumes which come from the burning phosphorus?

After all the white fumes have disappeared and the contents of the bell jar have become clear, the gas may be removed into wide-mouth bottles and tested. To remove the gas into a bottle, fill the bottle with water, invert, keeping the mouth beneath the surface, and tilt the bell jar so that the bubbles of gas can escape upward into the bottle. Test the nitrogen thus obtained, with burning a stick, with limewater, and by tasting and smelling.

Conclusion. — Describe nitrogen, giving its odor, color, taste, effect on limewater, etc. Does it burn, support combustion, or put out fire? Is it heavy like carbon dioxide or light like hydrogen?

Note. — The greatest caution should be observed in handling phosphorus, since it *ignites spontaneously* and its burn is *very dangerous.*

6. ACIDS, BASES, AND SALTS

Object. — *To learn the characteristics of acids, bases, and salts, and what is meant by neutralization.*

Apparatus. — Hydrochloric acid, vinegar, lemon juice, caustic soda, ammonia, limewater, test tubes, evaporating dish, and litmus paper.

Method. — (*a*) *Acids.* Put a few drops of hydrochloric acid or vinegar or lemon juice in a test tube and add an inch of water. Examine the mixture to determine the *taste, smell,* and *feeling.* Put in a strip of neutral litmus paper or a drop of litmus solution and note the change of color.

(*b*) *Bases.* Add water to a few drops of caustic soda, ammonia, or limewater, as in (*a*), and examine in the same way.

(*c*) *Neutralization.* To a test tube containing dilute hydrochloric acid add dilute caustic soda *drop by drop,* and test with litmus until it does not change color.

If in adding the caustic soda you get too much so that the color becomes blue, reverse the process and add the acid until the solution has no effect on litmus.

Instead of using litmus paper, a drop of litmus solution may be used to color the acid at the start, then when it becomes lavender, or just between red and blue, the solution will be at the neutral point.

This process of combining an acid with a base is called neutralization.

Now taste the contents of the tube. Is it sour like acids or bitter like bases? Does it have the roughish feel of an acid or the slippery feel of a base? Has it the sharp pungent odor of hydrochloric acid or the soapy smell of caustic soda? What does it taste like?

Conclusion. — State (*a*) the characteristics of acids, (*b*) of bases. What is meant by neutralization? What results from neutralizing hydrochloric acid with caustic soda?

Definition. — A salt is a substance which results from neutralization of an acid with a base.

Suggestions. — Test limewater, ammonia, fruit juices, milk, soap, saliva, molasses, etc., and determine which are acid, which are neutral substances, and which are bases.

II. FOOD MATERIALS AND HOW TO DETECT THEM

Nutrients

A nutrient is a chemical compound capable of nourishing the body. Foods are good for us because they contain one or more of these chemical compounds.

The nutrients are proteins, carbohydrates, fats and oils, water, and mineral salts.

Proteins always contain carbon, hydrogen, oxygen, and nitrogen, and they may also contain a few other elements, such as sulphur, phosphorus, iron, etc. Since they all contain nitrogen, they are often known as *nitrogenous* foods.

Carbohydrates are mostly composed of carbon, oxygen, and hydrogen. Sugars and starches are the principal carbohydrates. Fats and oils are rich in carbon and hydrogen.

Water forms a large part of most foods. Common salt is the principal mineral salt entering into food, but there are also compounds of lime, sulphur, phosphorus, and many other elements in various articles of diet.

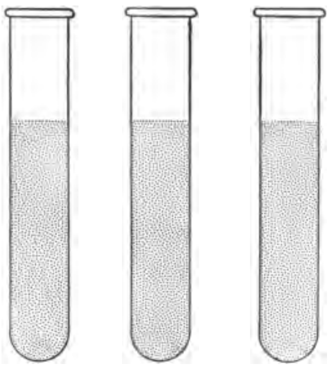
The following experiments will teach how to detect the presence of various nutrients in any kind of food.

7. PROTEIN

Object. — *To learn how to detect the presence of protein in food.*

Apparatus. — White of egg, lean meat, nitric acid, ammonia, Millon's reagent, biuret reagent, lamp, and test tubes.

Method. — (*a*) *Physical tests.* Put a small quantity of the egg in a test tube, add a little cold water, and shake the mixture vigorously. What happens? Stand the tube in a test tube rack for some time. Compare this tube with a tube containing clear water.



Biuret. Xanthoproteic. Millon's.
FIG. 4.

Heat a small portion of white of egg in water until it boils. What change does it undergo?

Burn a small piece of white of egg or lean meat and note the odor of the smoke. This peculiar smell is characteristic of nitrogenous substances. Name some other things which emit this odor when burning.

(*b*) *Chemical tests.* The yellow test (xanthoproteic). To a small portion of white of egg add a few drops of dilute nitric acid and heat the mixture. How does the nitric acid affect the raw albumin? What change of color follows heating? Now neutralize with ammonia. What is the final color?

The red test (Millon's). To another portion of egg albumin add a few drops of Millon's reagent and warm gently over a lamp. What change of color occurs?

Note. — Heat gently at first, or this test is not likely to work.

The violet test (biuret). To a small amount of soluble protein, for example, albumin or milk in water, add a little of the biuret reagent. What change occurs? Repeat this test, using only a drop of the egg solution in a very large quantity of water. This will show how delicate this test is.

Conclusion. — State briefly in not more than four sentences what are the tests for protein.

Suggestion. — Repeat these tests, using meat, cereals, flour, cheese, milk, bread, potatoes, and other articles, and determine which give the best tests for protein.

Note. — *Millon's reagent* is made by mixing one part mercury by weight with two parts nitric acid (concentrated commercial). When the mercury is all dissolved, dilute with twice the volume of water.

Biuret reagent is made as follows: to 1000 cc. of a 10 per cent solution of caustic soda in water, add drop by drop 10 cc. of a 3 per cent solution of copper sulphate, stirring constantly while the solutions are combining. The same test is obtained if the substance is first treated with strong caustic soda and then *very dilute* copper sulphate.

Another Protein Test

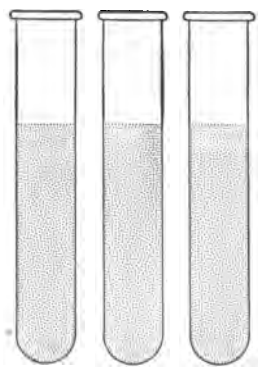
To a substance to be tested, add a drop of saturated cane sugar solution in water. Then add a drop of pure sulphuric acid. If proteins are present, the substance will assume a deep red color.

8. STARCH

Object. — *To learn how to detect the presence of starch.*

Apparatus. — Laundry starch, flour, potatoes, solution of iodine, test tubes, lamp, etc.

Method. — Place a little starch in a test tube with water. Shake it vigorously. Does it dissolve? Does it froth as the egg did? Filter and allow the filtrate to evaporate. Is there any starch residue?



Starch. Test. Iodine.

Fig. 5.

Heat the test tube gently over the flame. What change takes place in the color and general appearance of the starch?

Now add a drop of iodine solution to the starch paste. What happens? Heat. What happens? Cool again. Does the color return?

Test potatoes, flour, and other things mentioned, also milk, meat, eggs, etc. Which ones contain starch and which do not?

Conclusion. — State in one sentence how starch may be recognized.

9. STARCH (optional)

Object. — *To find out something of the appearance of starch grains.*

Apparatus. — Various kinds of starch which can be obtained from corn, wheat, rice, cannas, potatoes, etc., a compound microscope, and a razor for cutting thin sections.

Method. — Mount a drop of water containing starch of any sort and examine with a low power. Note the shape and structure of a grain. *Draw* starch grains.

In a similar manner mount and examine other kinds of starch. Wherein do these starches differ? In what respects do they agree? Cut thin sections of potato tubers and mount them in water. Note the starch grains packed in the cells.

Place a drop of iodine solution on the slide at the edge of the cover glass. Watch the solution as it works under and note the effect as it comes in contact with the starch grains.

Note. — Canna rootstocks contain very large starch grains.

Suggestions. — Scrape as finely as possible one or two large potatoes. Put the potato pulp in a large bottle with

cold water and shake it vigorously. Set it aside for a day and note the sediment on the bottom of the bottle.

Pour off the water and remains of potato pulp and examine the deposit on the bottom of the bottle. What is its color? Take out a little and boil it in a test tube of water. How does it change in color and consistence? Add a drop of iodine solution. What is the result? What is the substance obtained from the potato?

Add a teaspoonful of water to a heaping tablespoonful of flour and mix them thoroughly. When the water has taken up all the flour possible, remove the dough and wash it by holding it under a dripping faucet. Test the water which washes the dough. What does it contain? When the dough has been reduced to a grayish mass, test it for protein. Burn a little. Result?

Note. — In both these exercises, the separation can be hastened if the potato pulp or dough is placed in a cheesecloth bag and washed in clear water. In the first case, the pulp of the potato will remain in the bag while the starch will come through. In the second case, the starch will come through and the gluten, a protein, will be left in the bag.

Note. — Iodine solution is made by dissolving a teaspoonful of potassium iodide in a tumbler of water and then adding a few crystals of iodine. The solution should be of a rich wine color. Bottle the solution for future use.

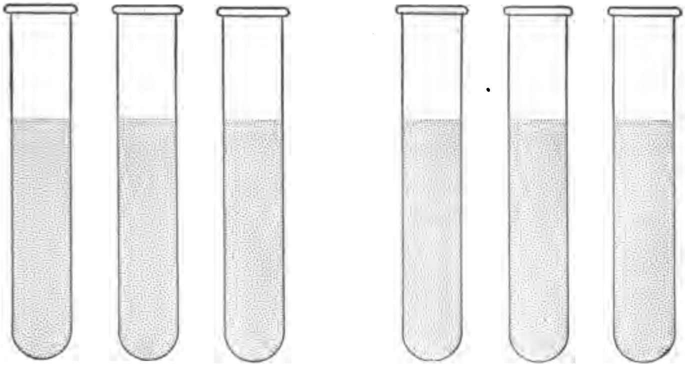
10. SUGARS

Object. — *To find out how to recognize (a) cane sugar and (b) grape sugar (glucose) in foods.*

Apparatus. — Cane sugar, glucose, raisins, figs, maple sugar, hydrochloric acid, Fehling's solution or Benedict's solution, tubes, lamp, etc.

Method. — (*a*) Put a few crystals of cane sugar into a test tube and add concentrated hydrochloric acid to the depth of ½ inch. Heat the mixture and notice the change of color.

(*b*) Place a raisin, a fig, or a small piece of glucose in water in a test tube and dissolve the sugar by shaking the mixture.



Cane sugar. Test. Hydrochloric acid. Grape sugar. Test. Fehling's solution.

FIG. 6.

To a little of this solution add a drop of Fehling's solution or Benedict's solution and heat it. What change occurs?

Conclusion. — In two sentences state the test for these two kinds of sugar.

Suggestion. — Test molasses and candies and find out which contain cane sugar and which contain grape sugar.

Test starch for grape sugar. Result? Test saliva for grape sugar. Result? Place starch paste and saliva in a test tube and set it aside in warm place for ½ hour. Then test the mixture for grape sugar. Result? What does this indicate as to the action of saliva in digesting starch in food?

Note. — *Fehling's Solution.* In a bottle labeled "Fehling's Sol. A" put 34.65 grams of cupric sulphate dissolved in 500 cc. of water.

In another bottle labeled "Fehling's Sol. B" put a solution of 125 grams of potassium hydroxide or sodium hydroxide and 173 grams of Rochelle salt dissolved in 500 cc. of water. Keep solutions "A" and "B" separate until ready for use, then mix equal portions.

Benedict's Solution. "With the aid of heat dissolve 173 grams sodium citrate and 100 grams sodium carbonate in about 600 cc. water. Filter into a glass graduate and make up to 850 cc. with water. Dissolve 17.3 grams copper sulphate in 100 cc. water and make up to 150 cc. with more water.

"Pour the carbonate-citrate solution into a large beaker and add the cupric sulphate solution slowly with constant stirring.

"The mixed solution does not deteriorate on long standing." — Hawk's *Practical Physiological Chemistry.*

11. GRAPE SUGAR

Object. — *To demonstrate the action of diastase in changing starch to grape sugar.*

Method. — Prepare a small quantity of very dilute starch paste. Add water until there is no appearance of starch, but on testing with iodine solution a clear blue is seen. Fill the test tube $\frac{2}{3}$ full of the starch. To one add a small quantity of diastase. Put both tubes in a warm place for 24 hours.

Now test both tubes for starch and for grape sugar. Result? Chew a bit of cracker or bread for three minutes. What change in taste takes place?

Note. — A substance which like diastase can act upon insoluble substances and change them into different soluble substances is called an *enzyme.*

12. OILS AND FATS

Object. — *To learn how to recognize oils and fats in foods.*

Apparatus. — Olive oil, beef fat, butter, flaxseed meal, castor beans, nuts, unglazed paper, ether, and an evaporating dish.

Method. — Oils and fats may be recognized by the fact that they make a grease spot on unglazed paper. They do not all yield their oil at once, and some require special treatment to extract it.

(*a*) *Contact.* Place a drop of olive oil on a piece of unglazed paper. Result?

(*b*) *Heat.* Place some flaxseed meal on the paper and heat it over a lamp or in an oven. Result?

(*c*) *Pressure.* Place some flaxseed meal or corn meal on the paper and apply considerable pressure. Result?

(*d*) *Solution.* Place any of these substances in a test tube, add ether, and shake the mixture. Then strain the filtrate and put it in an evaporating dish. Allow it to stand until the ether has evaporated and try the residüe on paper for grease spot. On account of its great inflammability ether should not be brought near a burning lamp.

Note. — A grease spot often looks like a wet spot. To tell one from the other, hold the paper over a flame. If it is a grease spot, the spot will spread and remain; but if a wet spot, it will dry out and disappear.

Some nuts are so rich in oils as to burn like a candle. This is particularly true of the Brazil nut. If the shell is removed and the kernel is held with one end in a lamp flame, it will take fire and burn for a long time, giving a clear white flame and very little smoke. Removal of grease spots from clothing by pressing with hot flat irons on brown paper is an application of *a*, *b*, and *c*, and the use of gasolene in "dry cleaning" is an application of *d*.

The Soudan III Test

Directions. — Make a grease spot on a piece of filter paper, using any substance which contains fats or oils. Saturate the paper with Soudan III and then wash it with alcohol. What occurs?

Repeat, using paraffin, beeswax, cocoa butter, vaseline, etc. How may oils be detected?

Note. — Soudan III is a stain used as a reagent in microscopic work.

Suggestion. — Make a list of oils and fats and the plants or animals which produce them.

Find out at least one use for each and any interesting facts concerning their manufacture.

To a test tube half full of water add a few drops of oil. Do they mix? Shake the tube vigorously and note the result. Add a few drops of caustic soda and shake the tube. Result? Examine a drop of milk under a cover glass, using a low power of the microscope. *Draw.*

Select several articles of food such as bread, cereals, meat, cheese, potatoes, etc., and test each for protein, starch, sugars, and fats. Which contain most of each nutrient? Tabulate your results.

The Alcanna Test

Make a solution of alcanna root in 95 per cent alcohol. Filter it and add an equal bulk of water. This solution gives a deep red color to oils and fats.

Suggestion. — Make very thin sections of castor bean or Brazil nut and examine for oil globules. Run a drop of the alcanna solution under the cover glass and watch the oil globules as they take up the color.

13. WATER

Object. — *To detect the presence of water in a food.*

Apparatus. — Various substances, such as cereals, meats, etc., test tubes, and a lamp or Bunsen burner.

Method. — Place the substance to be tested in a dry test tube and hold it over the flame for a minute. What collects on the inside of the tube? Continue to heat the tube, turning it in a slanting position.

Conclusion. — The presence of water may be detected by what means?

Note. — The steam which comes off at first is clear and condenses into water, but the water that comes off later is stained more or less by the products of destructive distillation of the substance used. To prove that it is actually water that comes off, put a drop of it on a little copper sulphate that has been heated until it has lost its blue color and become white. The copper sulphate will return to its former blue color. This test is not necessary in ordinary experiments.

Note. — Some mineral substances are destitute of water. Such substances are known as *anhydrous*, a word which means without water. Such substances are very rare. When a substance is deprived of its water, it is said to be *dehydrated*. Most such substances, if left to themselves, tend to absorb water and become hydrated. This is illustrated in the behavior of lime when it becomes *slaked*.

14. AMOUNT OF WATER

Object. — *To find out the amount of water in different articles of food.*

Apparatus. — A slow oven, and any article whose water content is to be determined, such as potato, radish, leaves of cabbage, etc.

Method. — Weigh the article carefully, then chop it fine and put it in an evaporating dish. Set it in a slow oven

and keep it there until all water has been driven off. To determine this, weigh from time to time, noting decrease until the weight becomes constant.

How much water does each article contain?

Note. — Care should be taken not to heat the substance so hot as to set it on fire. The substance should be *dried* and not charred.

15. MINERAL SALTS

Object. — *To prove that there is mineral matter in food stuffs.*

Apparatus. — Same as in Experiment 14.

Method. — After the water has been driven off as in the preceding Experiment, continue the heat until no gases come off. Then increase the heat and burn up the contents of the tube. If nothing remains, it is a sign that no mineral matter is present; but if ashes are left in the tube, it is an indication that mineral matter is there.

Substances like alcohol, ether, chloroform, benzine, gasoline, etc., leave no ash, therefore they are said to contain no mineral matter.

Conclusion. — State in one sentence how the presence of mineral salts is detected in foods.

III. DIFFUSION AND OSMOSIS

16. DIFFUSION

Object. — *To learn what is meant by diffusion.*

Apparatus. — A tall jar or bottle, some crystals of copper sulphate or potassium bichromate or any other highly colored salt soluble in water.

Method. — Place a few crystals of the salt in the jar and carefully cover it with water, letting it run down the side of the jar very slowly, and do *not* shake or stir the mixture. Let it stand for some time. What is the result? This tendency of substances to mix is called *diffusion.*

Conclusion. — State in a sentence what is the meaning of diffusion.

Note. — Gases also have this property and diffuse much more rapidly than liquids.

17. DIFFUSION

Object. — *Same as in Experiment 16.*

Apparatus. — A U-tube, gelatin, litmus solution, hydrochloric acid, caustic soda, potassium bichromate.

Method. — Soak the gelatin until it is soft and melt it over a lamp. Add a drop of potassium bichromate to render it insoluble, then add the litmus solution till it acquires a rich purple color. Pour it into the U-tube until it fills the bend and leave it in a cool place until the gelatin has set.

Now fill one arm of the U-tube with dilute hydrochloric acid and the other arm with dilute caustic soda. As these substances diffuse through the gelatin, they will color the litmus blue or red as the case may be, and the progress of the diffusion can be observed. If the solution is kept in a cool place, the potassium bichromate need not be added.

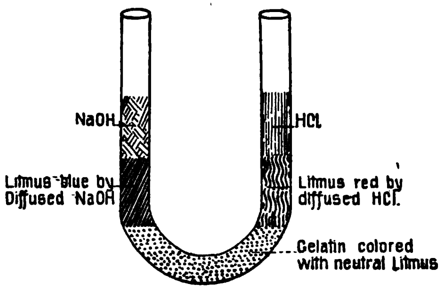


FIG. 7.

18. DIFFUSION

Diffusion may be shown in several other ways. It is not advisable to make much of this phenomenon since it does not enter very largely into elementary study of plants. Some of these exercises should therefore be optional.

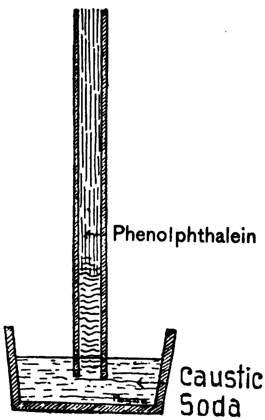


FIG. 8.

I. Arrange a U-tube as in Figure 7. Fill the bend with gelatin which has been rendered insoluble by addition of potassium bichromate. After the gelatin has set, fill one arm with strong copper sulphate and the other with potassium bichromate or any other highly colored salt. These liquids will diffuse and the advance can be observed as it goes on.

II. Fill a glass tube with gelatin to which a little phenolphthalein has been added. Stand the tube in a beaker con-

taining any alkali in solution. As the alkali diffuses upward through the gelatin, the phenolphthalein will take on the characteristic crimson color (Fig. 8).

III. Repeat this exercise, using gelatin colored with dilute acidulated litmus and alkali in the beaker. Neutralization is well illustrated by using a U-tube as in Figure 7 and filling the arms with acid and alkali, while the bend is filled with neutral litmus in gelatin.

IV. If copper sulphate and potassium ferrocyanide are used, they will meet and form a membrane in the midst of the gelatin.

19. OSMOSIS

Object. — *To learn what is meant by osmosis and dialysis.*

Apparatus. — Several collodion bags (see Note) or pieces of thin animal membrane (such as sheep gut or fish air bladder), starch, sugar, egg albumin, etc.

Method. — Suspend the bags in cups of clear water as follows: *A* containing starch paste, *B* containing sugar solution, and *C* a mixture of starch paste and sugar solution (Fig. 9).

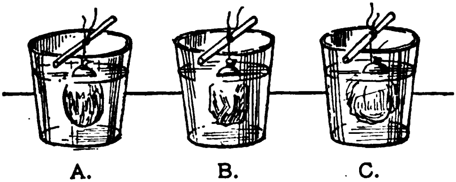


FIG. 9.

After a half hour, test some of the water outside of each bag for the substance which was put inside. Which ones have diffused through the membrane?

Diffusion through a partition is called *osmosis.*

Query. — Will starch, egg albumin, olive oil, sugar, or salt diffuse through a partition?

Dialysis

Test the liquid outside the bag *C* containing both starch and sugar. Does only one or do both substances come through the partition? In this way it is possible to separate diffusible from non-diffusible substances by using a membrane. This method of separation is called *dialysis*, and the partition used is known as a dialyzer.

Conclusion. — State briefly the meaning of the terms *osmosis* and *dialysis*.

Note. — A collodion bag is easily made by pouring collodion into a perfectly clean, dry, cylindrical dish and then pouring off all that will flow out. A thin film of collodion will thus be left lining the vessel. It may be removed by carefully loosening the edge and pulling it gently. To prevent tearing, a little water poured between the film and the glass will help to loosen it. Before trying to remove the film, hold the dish in the hand to warm it. This will hasten the evaporation of the ether contained in the collodion.

20. OSMOSIS

Object. — *To prove that osmosis may produce pressure.*

Apparatus. — An egg, a piece of glass tube, sealing wax, a tumbler.

Method. — With the point of a knife blade, carefully pick away the shell at the large end of an egg so as to expose the delicate skin (*membrana putaminis*) which lines the shell. But in no case let this membrane be ruptured.

Then pierce a small hole through the opposite end so as to expose the white of the egg.

Place the glass tube (*a*) over the hole and fasten it with sealing wax. Now arrange the egg in a glass of water so that the membrane is in contact with the water (*i*) (Fig. 10).

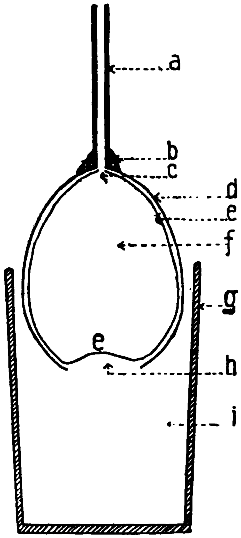


FIG. 10.—*a*, glass tube; *b*, sealing wax; *c*, puncture; *d*, shell; *e*, shell lining; *f*, contents of egg; *g*, glass; *h*, opening in shell; *i*, water.

Let the apparatus stand for a few hours and note the result. How do you account for this?

Conclusion. — State what you infer from the behavior of the contents of the egg.

The pressure which causes this rise of the contents of the egg in the tube is known as *osmotic pressure.*

Osmotic pressure may also be shown by using a thin rubber bag connected with a glass tube and filled with olive oil. If it be immersed in a vessel containing ether, the ether will pass through the partition and the contents of the bag will rise very rapidly in the tube. The bag must be surrounded with a cloth bag of the same size to prevent its becoming distended.

21. OSMOSIS

Object. — *To learn how the pressure due to osmosis may be measured.*

Apparatus. — A potato, cork cutter, cork, glass tube bent at right angles, sugar, and a shallow dish.

Method. — Cut off the lower end of the potato and remove the skin about one third of the way up to the top. With the cork cutter, bore a large hole to within ½ to ¾ inch from the cut-off end.

Now bore a small hole into the side of the potato above the peeled area. Coat the glass tube with vaseline and force it into the side hole so that leakage is impossible.

Then fill the large cavity with sugar and cork the top hole tightly.

Stand the potato in a dish and pour in water up to the height of the peeled area. Let it stand for two or three hours. What is the result? The height to which the liquid rises will measure the osmotic pressure.

Conclusion. — State how osmotic pressure may be measured.

22. OSMOSIS

Object. — *To show that osmosis may take place through the skin of a leaf.*

Apparatus. — A bell jar, a plate, a thick leaf of such a plant as the begonia, and a piece of paper.

Method. — Lay the leaf upon the plate and beside it place a piece of paper about the same size. Upon the leaf place a little pile of powdered sugar and put a similar amount upon the paper. Cover the plate with the bell jar and let it stand for several days, looking at it from time to time.

What happens to the sugar on the leaf? What happens to that upon the paper? Explain the difference. In view of what has been learned from the preceding experiments, how do you account for this?

Suggestion. — (*a*) Cut sections of beet root and place them in cold water.

(*b*) Boil sections of beet root and then place them in cold water.

What is the difference in the results?

(*c*) Immerse sections of beet root in wood alcohol, then remove them and place them in cold water.

How do you account for these results?

IV. SOIL AND SOIL PREPARATION

23. CONTENTS OF SOILS

Object. — *To learn what substances are found in the soil.*

Apparatus. — A trowel or shovel, a large pan or box, and a simple magnifying glass.

Method. — Dig up a pan full of soil. Be sure not to go too deep. Six or eight inches is about right for ordinary top soil.

Examine the soil to notice the following points: Does it break up easily? Is it lumpy? Does it contain stones? How does it feel to the hand? Is it gritty or soft? The color?

Can you detect any organic remains, such as dead leaves, decaying roots, etc., in it?

Now examine a small portion with the magnifier. What can you discover? Look for grains of sand, particles of clay, and vegetable remains.

Conclusion. — State what you find in the specimen studied.

Suggestion. — Examine soils from other places in the same way.

Query. — How does garden soil differ from forest soil, roadside soil, meadow soil? How does the soil near the surface differ from that farther down?

Examine the exposed surface where cellars or other excavations are being made, and note how the soil changes in color and make-up as the depth increases.

24. CONTENTS OF SOILS

Object. — *To prove that there is water in soil.*

Apparatus. — Any kind of soil, scales, a pan or earthen dish for heating.

Method. — Carefully weigh any convenient amount of soil and place it in a pan or evaporating dish. Set it in a slow oven and let it remain there for several hours. Weigh it from time to time and continue the drying process until the weight becomes constant.

Do not overheat the sample, for it is not desired to burn up any of the organic constituents.

After the weight has become constant, find the difference between the first and last weighings, and this will be the amount of water contained in the sample examined.

Investigation. — Examine various soils in this way and find which contain most water. How do woodland soils compare with roadside soils and garden soils? How do sandy soils compare with loam and clayey soils in water content?

25. CONTENTS OF SOILS

Object. — *To find out the amount of mineral matter and organic substance in a given specimen of soil.*

Apparatus. — Same as in Experiment 24.

Method. — Proceed as before until all water has been driven off. Then increase the heat so that all organic substances may be burned. When only ash and such other substances as will not burn are left, again carefully weigh the specimen. The final weight will indicate the amount of mineral matter in the specimen. How is the organic part to be determined?

Suggestion. — Mix the last residue with water and *filter* it. Evaporate the filtrate to drive off the water. The resulting material will show the amount of soluble mineral contained in the soil. The *soluble* parts are of course the *plant foods.* The insoluble residue will be left in the filter.

Compare different soils as in Experiment 24 to determine which are richest in soluble mineral salts. The relative fertility of a given soil can thus be determined.

For comparison, the following table may be made: —

1. First weight	16 oz.
2. Loss through drying.	
3. Amount of water	
4. Loss through burning	
5. Amount of organic material	
6. Final weight . . . . (mineral matter)	
7. (*a*) Insoluble	
8. (*b*) Soluble (plant food)	

Note. — See action of roots in producing acids which dissolve minerals not soluble in water (Ex. 84), thus changing them to liquid form so that they may be absorbed.

26. CONTENTS OF SOILS

Object. — *To show that there is air in soil.*

Apparatus. — Straight glass vessels such as battery jars or graduate glasses, soils of various kinds, and water.

Method. — Accurately mark with a rubber band or paster a level one half the height of the jars. Fill the jars with water to the mark and then add equal volume of soil slowly to prevent slopping. Both soil and water should be measured first to insure accuracy. If the volume of the mixture

is equal to twice the volume of each, the soil contains no air. If less, the difference indicates the amount of air in the soil.

Suggestion. — Compare loose soils with compact soils. Which contain most air? Compare plowed soil with unplowed soil. Result?

27. CHARACTER OF SOILS

Object. — *To show what kinds of soil best retain water.*

Apparatus. — A frame with lamp chimneys arranged as in Figure 11. Each lamp chimney is closed with a perforated rubber

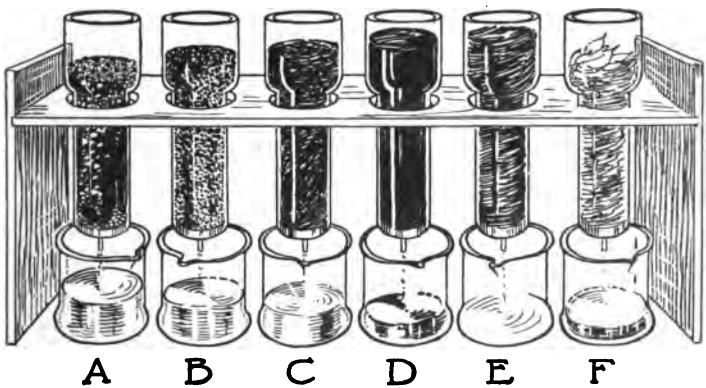


FIG. 11.

stopper and has a short piece of glass tubing to carry off the water, which drains into beakers.

Method. — Place various soils in the chimneys. In

A, 100 grams of gravel.
B, 100 grams of sand.
C, 100 grams of roadside soil.
D, 100 grams of rich garden soil.
E, 100 grams of leaf mold from forest.
F, 100 grams of dry leaves pulverized.

Pour 100 cc. of water into each chimney and note into which beaker the most water flows. Which kind of soil holds water best? Which least? Which is best for plants?

Conclusion. — State the result of these observations.

28. CHARACTER OF SOILS

Object. — *To find out something of the productiveness of different soils.*

Apparatus. — Samples of five or six different soils selected from different localities and sifted (specimens from different neighborhoods are preferable), a flowerpot for each sample to be tested.

Method. — Fill the flowerpots, each with a different sample of soil, and label them.

Plant in each flowerpot the same number of seeds of the same kind. Place the flowerpots in a location favorable for growth and leave them until the plants mature.

Compare the plants in all the flowerpots. Have all grown with equal vigor? Have all produced the same amount of flowers, fruit, and seeds?

Conclusion. — What may be inferred as to the productiveness of the various soils tested?

Query. — Do slopes of hills and mountains furnish a richer or a poorer soil than valleys? Give reasons for your answer. Has color any relation to fertility? Fineness?

29. CHARACTER OF SOILS

Object. — *To show the benefit of drainage in soils.*

Apparatus. — Two fruit cans, soil, and seeds.

Method. — With a nail punch several holes in the bottom of one can. Fill both cans with the same soil, which has been broken up very fine and soft.

Plant the same number of beans, peas, or corn seeds in each can and set them side by side in a favorable location for growth. Water both cans daily with sufficient water to keep the closed can saturated and the open one only moist. Do not water too much, but be sure that each can gets the same amount every day. At the end of two or three weeks note the soil in each can. What is the result in growth of each plant? Why?

Conclusion. — What does this teach us as to drainage in soil?

30. CHARACTER OF SOILS

Object. — *To show the relation of drainage to temperature of the soil.*

Apparatus. — Fruit cans, soil, seeds, and a chemical thermometer.

Method. — Punch holes in the bottom of one can. Fill both cans with the same kind of soil. Plant seeds in them and water thoroughly so that the water comes to the top of the earth in the unpunctured can.

Set both cans side by side in a sunny window.

From time to time thrust the thermometer bulb into the soil about an inch below the surface and record the readings of each can. If a piece of white paper is wrapped about each can and fastened with a rubber band, the readings can be recorded when made.

After a day or two compare the readings. Which shows the higher temperature at the start? Which one later in the day? What happens in the drained can? What is the effect of drainage on the temperature of soil? How do you explain this?

Conclusion. — How does drainage affect the temperature of the soil?

Query. — What effect on growth of crops has under-drainage of a field? Does the color of soil have any effect on its capacity for absorbing and holding heat?

Note. — Where the amount of water in soil is excessive, the spaces between the soil particles become filled with water to the exclusion of air. Such a soil is said to be saturated. It is unfit for cultivation of all ordinary crops. Rice is the only cereal which can be grown in very wet soils.

31. EFFECT OF TILLING

Object. — *To demonstrate the benefit of tilling the soil.*

Apparatus. — Flowerpots, soil, and seeds.

First Method. — Fill a flowerpot with coarse lumpy so and another with the same soil which has been crumbled fine.

Plant seeds of corn, squash, or other quickly germinating seed. Water both alike and stand them in a favorable location. In which does germination start first? Which plants thrive best? How may this be explained? Why is soil plowed and harrowed?

Conclusion. — What sort of soil is best adapted to the germination and growth of young plants?

Note. — Experiments in tilling the soil are better made in school gardens when possible. Space in flowerpots is not sufficiently large to present such exercises to the best advantage.

Second Method. — Put equal weights of soil in two flowerpots. Pack the soil down firmly in each flowerpot, then loosen up about two inches depth of one. At the end of a week weigh both flowerpots. Which has lost the greater amount of moisture? Why? How does this exercise illustrate soil tilling?

If it is desired to illustrate this more graphically, the following device may be employed.

Place a cube of loaf sugar in a beaker. Pile as much granulated sugar on top as it will hold. Beside this place another cube of sugar without any granulated sugar upon it. Now add a small quantity of red ink to the dish and note rapidity with which it rises through the sugar cubes.

In which does it rise more rapidly? Can you explain why? Wherein is this exercise like the preceding? The loose aërated stratum on the surface of tilled soil thus prevents the too rapid loss of soil water through evaporation. The sugar experiment is not precisely similar to what happens in soil, but the phenomena are analogous.

Suggestion. — To show that germination is hindered or prevented by lack of air in the soil, fill two flowerpots with heavy loam or clay soil and plant some seeds.

Leave the soil in one flowerpot loose, mellow, and moist; but add enough water to the other to puddle it so that the clay surface becomes packed while wet.

In which soil do the seeds germinate first?

32. EFFECT OF TILLING

Objects. — *To study the effect of worms on soils.*

Apparatus. — Flowerpots of rich soil, one or two free from worms, one or two containing two or three earthworms, and one or two with five or six earthworms.

Method. — Plant tender seedlings in each flowerpot, water them, and stand them in a place favorable for growth. After several days examine the surface of the soil for worm casts. Continue observations for several weeks, or until definite results are apparent.

Conclusion. — How do earthworms modify the soil? What is the effect on the growth of the plants?

Suggestion — *Drainage.* Study the soils about the school or home. When it rains, what sort of soils absorb most water? On what kind of soils do puddles accumulate? After a puddle has dried up examine the bed of its pool and find out what kind of soil covers it.

Fill several flowerpots with soils and pack them down tightly. Then water them well and let them stand for some time. Which soils let the water pass through most readily? Which remain damp longest? Which crack in drying?

From your observations what kind of soil is best for letting air and water down to the roots of plants?

Earthworms. Examine the surface of the ground early in the morning and look for wormholes and worm casts near these holes. How does the earthworm modify the soil?

Look for bits of leaves that have been dragged into wormholes by the worms. Show how worms benefit the soil (*a*) by opening holes in it; (*b*) by dragging down trash from the surface; (*c*) by bringing up the worm casts and leaving them above on the surface.

Farming. Why does the farmer sometimes sprinkle sand or coal ashes over a clayey field before plowing it? If you had a very sandy field, how might it be treated to make it hold moisture better? Why? What effect on retention of moisture would it have to spread leaf mold on a field before plowing it?

V. FIELD WORK OR REFERENCE WORK

Exercise I. Fertilizing

(See also Experiments 95–98.)

Visit a farm in early spring or in autumn before the fall plowing is done. What is the reason for fertilizing the soil? What are the chief substances used for this purpose? Which ones are of mineral origin? Which are of vegetable origin? What ones are supplied by animals? What is meant by rotation of crops? Of what advantage is this? Find out what crops may be so rotated.

What crops exhaust the soil most rapidly? What kind of fertilizers are best for corn, wheat, potatoes, tobacco, cotton, and other staple crops?

How are the fertilizers applied to the soil? What precautions must be observed in using fertilizers? What chemical elements are supplied by using *lime*, *phosphates*, *bone fertilizer*, *stable manures*, *wood ashes*, and *green clover?* What results if commercial fertilizers are used in excessive amounts? What fertilizers are best for gardens, for orchards, and for lawns?

Exercise II. Tilling

Describe a plow. How is it used? What is the object of plowing? When is deep plowing used? When shallow? How should the soil be turned? Why should it not be completely inverted? Find out three reasons for plowing. Why is it best to pulverize the soil as much as possible in plowing?

Describe a harrow. What is its use? What relation have plowing and harrowing to aëration and moisture of soil? What effect on heat of soil? Why is a roller sometimes used after plowing and harrowing?

Exercise III. Planting

Learn through observation in the field how the following crops are planted: wheat, corn, potatoes, tobacco, and cotton. Learn also how five principal vegetables are planted. What crops are transplanted? Of what use are cold frames, hot beds, and forcing houses to the truck farmer? Why do truck farms abound near cities, while staple crops are grown farther away? What crops are sown broadcast upon the prepared soil? Describe a seeder, or planting machine. What advantages are gained by seeders over the old hand methods other than that of time and labor saving?

Exercise IV. Cultivating

What implements are used for cultivation of crops? Describe a cultivator. Why is constant stirring of the soil an advantage to the crop? What necessary things are admitted to the soil by this treatment? What objectionable things are got rid of in this way? Compare a field or garden which has been properly cultivated with one which has been neglected. How do the plants compare in vigor and in the amount of fruit produced? How does cultivation modify the following crops: potato, corn, celery, asparagus, tomato, rhubarb, and peanut?

Exercise V. Harvesting

Note. — The gathering of any crops is known as harvesting. The manner of harvesting depends upon the kind of crop. Thus

cereals are harvested with great machines known as harvesters; potatoes are harvested with a digging machine; eggplants are cut with knives; and grapes are severed with shears.

Visit a wheat field at harvest time and observe the process, making note of each step. If possible, visit a great wheat field where the whole process is accomplished by one machine. Compare old methods — reaping, threshing, winnowing, etc. — with the most recent way of doing this work.

Visit a truck farm at any time during the summer and make note of the way in which the various small fruits and vegetables are gathered and prepared for marketing.

Exercise VI. Marketing

Visit a commission merchant's place of business at any season. Make a list of products by seasons, together with the localities from which they come. In what form does each product reach the market? What products come in baskets, in barrels, in crates?

Select ten fruits or vegetables and find out, by reading or by inquiry, where and how they are grown, how cultivated, harvested, and shipped, and how used by man.

Exercise VII. Flower Gardening

Visit a large city park and study the process of flower culture as it proceeds from season to season: —

1. The forcing houses where seedlings and cuttings are being prepared for outdoor bedding;

2. The preparation of soil in the beds and setting out of bulbs and other plants;

3. The removal of early plants to make way for later ones, for example, tulips and hyacinths making way for coleus and geraniums;

5. The harvesting of seeds for future use and the removal of dead summer growths in order to set out bulbs for next spring.

Note. — For city schools where the foregoing exercises cannot be taken as field work, the same and similar topics can be worked up through reference to libraries. The various publications of the United States Department of Agriculture and the reports of the state experiment stations will furnish abundant material for reference.

VI. SEEDS

33. PARTS OF A SEED

Object. — *To find out the parts of a seed.*

Apparatus. — Beans, peas, squash seeds, castor beans, horse-chestnuts, or any other large seeds.

Method. — Examine the seed and note its color, surface, and markings. Look for a scar (the hilum) which shows where it was attached to the inside of the fruit. Look for a small swelling (the chalaza) which is sometimes seen on the outside of seeds. Look for the ridge (raphe) which runs around some seeds. Look for a tiny hole (micropyle) which penetrates the shells of some seeds. Describe and draw the outside view of each seed studied and name all parts shown.

Conclusion. — In one sentence state the parts which you find common to all the seeds examined.

34. EFFECT OF SOAKING

Object. — *To find out the effect of soaking seeds.*

Apparatus. — Several dishes or bottles, water, and an assortment of seeds, as beans, peas, etc.

Method. — Examine the seeds, noting the size and feeling of the testas. Then place them in bottles and cover them with water. Examine from time to time for several hours. What change first takes place? Where does this change begin? How do you account for this? How does it spread?

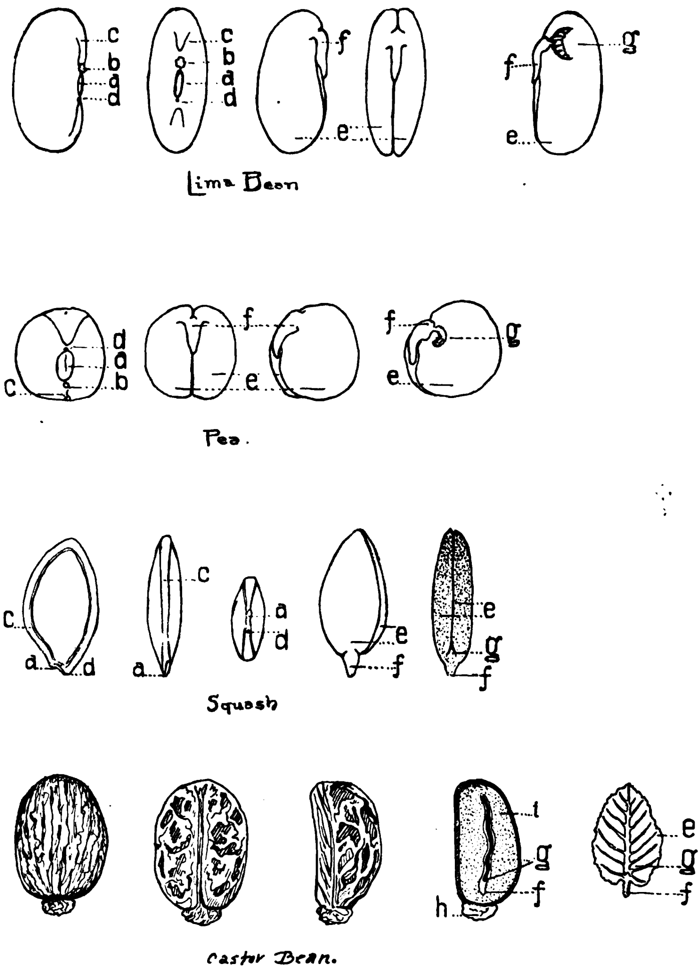


FIG. 12. — *a*, hilum ; *b*, chalaza ; *c*, raphe ; *d*, micropyle ; *e*, cotyledon ; *f*, hypocotyle ; *g*, plumule ; *h*, caruncle ; *i*, endosperm.

When the seeds have become soaked and fully expanded, examine them again. What change has taken place in the

size of the seeds? Why? Pinch the seed. Does any water come out? If so, where?

Conclusion. — State what is the effect of soaking seeds; also what changes take place and where the water probably gets into the seed.

35. EFFECT OF SOAKING

Object. — *To study the effect of water on dry seeds.*

Apparatus. — Seeds as in the preceding Experiments.

Method. — Weigh a given number of the seeds dry. Then place them in a beaker and cover them with water. Let them stand over night. Then remove them, dry them with blotting paper to remove superfluous water, and weigh them again. Have they increased in weight as well as in size? How much?

Conclusion. — State what is the effect of soaking on the weight of seeds.

36. SEEDS EXERT PRESSURE

Object. — *To show that seeds in absorbing water exert pressure.*

Apparatus. — Bottles of any sort (the square or flat-faced bottles of thin glass are very good for the purpose), beans or peas.

Method. — Fill the bottles with dry seeds. Add water enough to fill up the spaces around the seeds in one bottle. Leave the other as control. Cork the bottles and allow them to stand. After three hours note the result. If the cork has been pushed out or if the bottle has been broken, what does the experiment show? If the bottle remains intact, remove the cork and try to shake out the seeds by inverting it.

Conclusion. — Inference from this experiment.

Suggestion. — Repeat this experiment, using four bottles, filling one pair with fresh live seeds and the other pair with seeds which have previously been killed by heat in an oven. Fill one of each pair with water as before. Cork them and set them away to await results.

Does expansion occur equally in all preparations?

Is the result due to *mechanical* or to physiological causes? Give reasons for your answer.

37. SEEDS EXERT PRESSURE

Object. — *Same as in Experiment 36.*

Method. — Repeat Experiment 36, using flowerpots, bricks, and wire as follows: Fill a flowerpot with dry seeds. Place a brick over the top and wire it on firmly. Then immerse the whole in a pail of water and leave it overnight.

Lift the flowerpot carefully out of the water and note the result. If the brick has been fastened down firmly, there will be something worth seeing. How can you account for the result?

Query. — Is this power of exerting force of any use to the seed in getting started under the ground?

Note. — A piece of board may be used instead of a brick in this experiment. In this case the board may be bent and the flowerpot not broken.

An *embryo* is an immature or undeveloped plant or animal. Every seed contains such a plant surrounded by one or more coverings called seed coats, which serve to protect it.

There is also laid up within the seed a quantity of food for the use of the embryo when it begins to grow. This food is sufficient to nourish the plant until it has developed root and leaf surface enough to manufacture food for itself.

38. THE EMBRYO

Object. — *To find the embryo in a seed and to learn how it is protected.*

Apparatus. — Beans, peas, or other large seeds used in the preceding Experiments.

Method. — Select a large soaked seed and carefully remove the outer covering (testa). What is found under this outer coat? Remove all the coverings and examine each.

After all coverings are removed the kernel remains. Examine the kernel (embryo) and find its three parts. What are they? Draw the kernel and name all parts found. The bean clearly shows a thick pair of seed leaves, a pointed stem, and a small bud consisting of two tiny leaves between the seed leaves. (See Figure 12.)

Conclusion. — Name the parts of an embryo and state how many coats protect it.

39. COMPARATIVE STRUCTURE

Object. — *To discover what parts of a seed are essential and the relation of certain structures to each other.*

Apparatus. — Beans, peas, and other large seeds as in the preceding Experiment; also almonds, horse-chestnuts, squash, acorns, peach pits, and seeds of pine, four-o'clock, and morning-glory.

Method. — Examine, study, and compare the several sorts of seeds, part by part. Which have thick testas, thin testas, smooth, rough, or wrinkled testas?

Which have one coat? Which have two? In which is there a third coat? In which is there a raphe? a caruncle? a chalaza? (Fig. 12.)

Compare the seeds, noting relative position of hilum and

micropyle. Remove the testas and compare the embryos part by part. Which have thick seed leaves? In which are the seed leaves thin? (Dodder has none.) In which are there more than two? In which seeds is there an endosperm? What relation seems to exist between the size and thickness of seed leaves and the amount of endosperm? In which is the plumule (first bud) large and distinct?

Conclusion. — State what parts are found in all seeds and the relation which exists between the size of plumule and thickness of seed leaves.

40. SEEDS WITH FOOD OUTSIDE THE EMBRYO

Object. — *To find out the structure of castor beans.*

Apparatus. — Several large castor beans.

Method. — Study the outside of the castor bean as before. Then carefully crack the brittle shell by giving it a little tap with a pencil.

On removing the testa notice the thin inner skin which covers the kernel of the seed. (*a*) Run a pin around the edge, being careful not to penetrate too far into the kernel. Separate the two halves and find the embryo as it lies embedded in the food (endosperm). (*b*) Select another seed, and having removed its testa as before, cut it lengthwise through the middle. Note the embryo as it lies buried in the thick endosperm.

How many seed leaves do you find? Are they thick or thin? Large or small? Find the pointed end. Can you find a bud between the seed leaves?

Examine the food (endosperm). Note its thickness. Test it for oil by crushing on unsized paper.

Conclusion. — State in one or two sentences the peculiar-

ities of a castor bean, making mention of the number and character of its seed leaves and the place where food is stored.

Suggestion. — Study seeds of morning-glory, four-o'clock, and buckwheat. Soak them well, and study them, using a magnifying glass.

41. SEEDS WITH ONE SEED LEAF

Object. — *To learn the peculiarities of a grain of corn.*

Apparatus. — Several grains of corn (yellow or red field corn is good, but the large Western corn is most desirable), an ear of corn.

Method. — Examine the corn grains after having soaked them for at least twelve hours.

(*a*) Observe the hard, horny covering, the stump where it was once attached to the ear, the lighter-colored depression called the *dent*, and the tiny scar near the tip of the dent where the corn silk was once attached.

These points will be more plain if an ear of corn is used for demonstration.

(*b*) Cut several sections of corn grains, lengthwise, crosswise, and flatwise, trying to cut exactly through the middle of the dent each time. Examine the cut surface and find the embryo surrounded on three sides by a starchy and oily mass of food (endosperm).

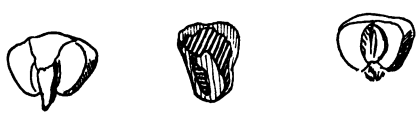


FIG. 13.

To determine the starchy part is easy because of its chalky appearance; but if the sections are soaked in iodine solution, the parts will all be seen very clearly (Fig. 13). Iodine colors the starch black or dark blue, and stains the embryo yellow or orange.

Make out all the parts and sketch the various sections.

Conclusion. — State the peculiarities of a grain of corn, making mention of the number of seed leaves and the location of the food.

Note. — All seeds are of one of two classes; namely, those having two seed leaves (cotyledons), like bean, pea, etc., and those having only one seed leaf, like corn. Some seeds, such as those of the pines, have more than two cotyledons. Such embryos are said to be polycotyledonous. The orange seed sometimes has from two to seven cotyledons of unequal size; but this is a monstrosity. Polycotyledons are regarded as dicotyledons whose seed leaves are cleft into two or more parts. Dodder seeds are destitute of cotyledons.

Most seeds of monocotyle plants are so small that the single cotyledon is not always easily seen. It is therefore often a better plan to leave this fact to be shown later, after germination.

Suggestion. — Study other large seeds, such as the date, wheat, Brazil nut, etc., and notice the similarity. In what remarkable respects does the coconut differ?

Food Materials in Seeds

Select any number of seeds and test each sort for the various nutrients.

Find answers to the following: —

1. What nutrients are found in wheat? In corn, rye, rice, barley, beans, peas?
2. Does an orange seed contain starch?
3. Is oil found in apple and pear seeds?
4. Do various nut meats, which taste so sweet, contain sugar?

Seed Extractives

Some seeds contain bitter or poisonous oils. These serve to protect the young from destruction by animals. Vanilla,

tonka beans, opium poppy, castor oil, and croton oil are well-known examples.

Taste the seeds of oranges, lemons, apples, peach pits, and bitter almonds.

Caution. — Peach pits, orange seeds, bitter almonds, and many other kinds of seeds contain prussic acid, a deadly poison. Hence it is not wise to taste of unknown varieties.

Some seeds are commercially valuable on account of essential oils contained in them.

Larkspur seeds furnish a poison used to kill lice.

Stramonium and belladonna are powerful poisons extracted from seeds of two plants of the nightshade family.

The betel nut yields a narcotic used in the East.

Pepper, mustard, nutmeg, cola, cardamom, and many other seeds are valued because of oils which yield flavors or spices.

Suggestion. — Visit a drug store and make a list of seeds used for medicine, flavors, etc. Visit a grocery and make a similar list of seeds used for food.

What precaution should be observed in mills and grain elevators to keep the seeds from sprouting?

Suggestion. — Visit a malting house and observe the process of making malt. Procure some grain not yet malted and compare it with that which has been malted. Test both for starch and for grape sugar. How do they differ?

Note. — It will be seen that starch changes into grape sugar during germination. This is effected by a substance called diastase, which is known as a ferment because it can cause fermentation. This change is necessary to the plant, since the starch is not capable of diffusing through the tissues of the plant. But by being changed to sugar it can be carried to all parts of the plant.

43. THE WATER FACTOR

Object. — *To find out whether all seeds require the same conditions of water to grow.*

Apparatus. — A shallow pan, a plate of glass 4 in. × 12 in., blotting paper, and assorted seeds.

Note. — Small seeds, such as lettuce, clover, alfalfa, timothy, blue grass, and the grains, are better than others for this experiment.

Method. — Cover the glass plate with one or two thicknesses of blotting paper and plant the seeds upon the paper

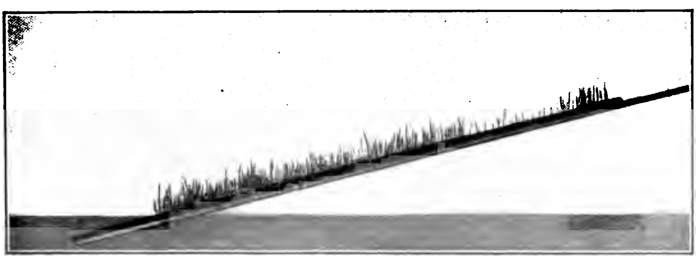


FIG. 15.

in straight rows from end to end. Then place the covered plate so that one end rests on the bottom of the pan and

the other on a side, thus forming an inclined plane. Now add water to the tray slowly so that it may be absorbed by the blotting paper without the lower seeds floating off. Gradually the water will pass up the paper by capillary force and after a time the whole will become moist. But the amount of water will vary with the distance from the level in the pan, and thus the seeds upon the blotter will receive varying amounts of water, depending upon their nearness or remoteness from the water in the pan. Leave the apparatus in a warm room for several days and note the result. Do all the seeds sprout alike? Do the same seeds sprout equally well at all distances from the water?

Conclusion. — State what you infer as to the need of water by growing seeds and whether all seeds are alike in their water requirements.

Note. — The water in the tray should be kept at the same level and the atmospheric conditions should be kept uniform if possible.

44. THE HEAT FACTOR

Object. — *To find how to make the embryo plant begin to grow.*

Apparatus. — Three bottles arranged as in Experiment 42, or three plates with blotting paper and cover glasses.

Method. — Prepare the seeds in damp sawdust (*B*, Experiment 42), or plant them on wet blotting paper on plates and cover them with plates of glass.

Now place the bottles or plates in three different localities where they will be alike in all respects save amount of heat.

Put *A* where it is very cold, as in a refrigerator if in summer, or on the outside of a window sill if in winter. Place *B*

in a warm place, as upon a desk where the temperature is never excessive. Put *C* upon a hot radiator or in an oven.

After five days bring the preparations together and compare the results.

Do the seeds exposed to the cold grow?

How about those in the warm place and those in the hot place?

Now remove all three preparations to the same warm location and allow them to remain for three days longer. Do the seeds in *A* and *C* grow? Does the cold hinder growth or kill the embryos? Does the heat kill or merely hinder?

FIG. 16. — Effect of heat.

Conclusion. — State your inference as to the effect of heat in making seeds sprout, also the amount necessary and the effect of extreme heat and cold on germination.

Query. — In buying seeds for planting is it advisable to purchase "sun-dried" or "kiln-dried" seeds? Why?

45. THE AIR FACTOR

Object. — *To find out how to make the embryo plant begin to grow.*

Apparatus. — Two wide-mouth bottles, sawdust, and seeds. One of the bottles having a cork so that it may be tightly stoppered.

Method. — Plant the seeds in damp sawdust, packing them in quite tightly to exclude as much air as possible. Then

Fig. 17. — Effect of air.

cork one bottle tightly, but leave the other open to the air. Place both bottles in a warm place where the heat conditions are just right. Thus the seeds are exactly alike in their conditions for germination except the supply of air. After five days note result. Continue observations for a month.

Conclusion. — State the result of your observations as to the effect on germination of shutting off the supply of air.

46. THE AIR FACTOR

Object. — *Same as in Experiment 45.*

Method. — Arrange six bottles containing damp sand in varying amounts as in Figure 18. Plant the same number

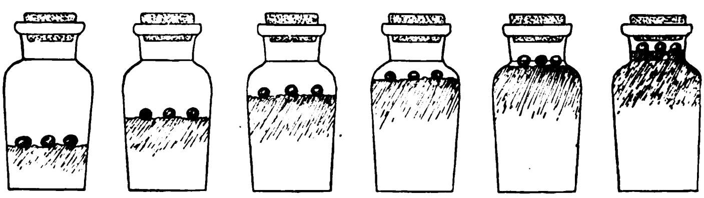


Fig. 18. — Effect of air.

of seeds in each bottle. Obviously the amount of air will also vary, bottle (1) having most air. Place the bottles where the heat supply will be alike for all. Cork tightly

and after ten days note the result of growth. This result indicates that some part of the air was used up. What is it? Test the air in each bottle, using a lighted stick. What gas has been given off by the germinating seeds? Test with limewater. Result? See also Experiments 45 and 49.

47. THE AIR FACTOR

Object. — *To find out whether seeds can germinate without oxygen.*

Apparatus — Two wide-mouth bottles, glass and rubber tubing, stoppers (perforated for two tubes), hydrogen generator, seeds.

Method. — Select several seeds which have already begun to sprout, carefully remove their testas, and place an equal number of seeds in each bottle. Now fill one bottle with water which has been boiled to drive off the air, insert the stopper, and push it down until the water rises to the top of the short tubes (*a*) and (*b*). Now generate hydrogen as in Experiment 4, and when you are quite sure that no air remains in the flask (see Note), invert the bottle so that the mouth is submerged, and connect (*b*) with the delivery tube. The hydrogen will rise through the water and drive it out through the tube (*a*). When all the water has been expelled, the seeds will be in an atmosphere of hydrogen, which is harmless; and as long as the mouth remains under water, no oxygen can enter.

The other bottle is to be filled with air to act as a control in this experiment.

After some days make observations on the two sets of seeds and see which are in best condition.

Conclusion. — State what you conclude is the effect on growth of depriving germinating seeds of oxygen.

Note.— To be sure that no air remains in the flask let the generator work for some time after several test tubes of hydrogen have been taken and tested for hydrogen.

Suggestions. — 1. Make an assortment of seeds and arrange each kind in as many different positions as possible; for example, hilum upward; hilum downward; hilum to right, seed on *edge;* hilum to right, seed on *side;* etc.

Germinate the seeds. Make sketches representing the various turnings and twistings which the hypocotyl is compelled to make in order to get into right relation to the soil.

2. Make another assortment, selecting seeds of various sizes, and plant five or six of each size, varying the depths of each. After one or two weeks observe results. Has depth of planting any relation to the size of seeds?

3. Compare old seeds with fresh ones of the same kind in their ability to germinate. How does age affect vitality of seeds?

48. RELATION OF DEPTH TO GERMINATION

Method. — Arrange a series of flowerpots containing soil. Plant seeds in them as follows : —

Pot I, five peas on the surface.
Pot II, five peas one inch deep.
Pot III, five peas two inches deep.
Pot IV, five peas three inches deep.
Pot I, five clover or alfalfa seeds on the surface.
Pot II, five ditto one inch deep.
Pot III, five ditto two inches deep.
Pot IV, five ditto three inches deep.
Pot V { five ditto $\frac{1}{4}$ inch deep.
five ditto $\frac{1}{2}$ inch deep.
five ditto $\frac{3}{4}$ inch deep.

Set the flowerpots in a locality favorable for growth and water them well. From day to day observe results. Which come up earliest? Which had most work to do in order to come up? Which are the larger seeds? Is there any relation between size of seeds and depth of planting? Of size to the early seedling? What sort of seeds does the farmer sow? What ones are planted? Probable reason for this?

The Pocket Garden

It is often desirable to have a means of constant observation on seedlings during germination. This is accomplished by what is known as a pocket garden or pocket germinator.

Procure two pieces of glass of any convenient size. Lay one on the table and cover it with four or five layers of blotting paper or flannel. Colored paper or cloth is preferable, since the delicate growths show most clearly on a dark background.

Now lay four thin strips of wood along the edges. Cigar box covers are of about the right thickness.

Moisten the blotting paper or cloth and sprinkle over it a few small seeds, such as radish, mustard, oats, or canary seed.

Cover the top with the other glass and bind the whole together with strips of bicycle tape or with common cord.

Many observations can be made on seedlings germinated in this way.

49. RESPIRATION

Object. — *To prove that germinating seeds give off carbon dioxide.*

Apparatus. — As in Figure 19.

Method. — In a wide-mouth bottle place a small vessel of limewater and fill around it with germinating seeds. Cork the bottle tightly to prevent entrance of air.

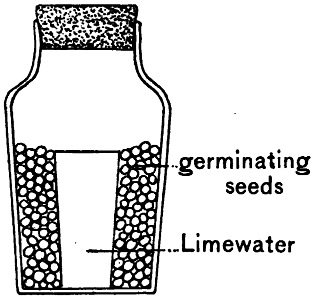


FIG. 19.

After three days remove the cork. Test the gas above the seeds with a burning stick. Result?

Examine the dish of limewater. What change has taken place in it? Proof?

Conclusion. — What is given off by germinating seeds?

Note. — See also Experiment 46.

Note. — A device to show that germinating seeds use up the oxygen of the air and set free carbon dioxide may be arranged as follows: —

Germinate some oats, wheat, or other similar seeds by planting soaked seeds between folds of wet flannel or blotting paper. When the roots and shoots are well started, fill the large end of a thistle tube with them and close it with a cork.

Now clamp it in a vertical position so that the small end will rest in a beaker of strong potash water or limewater.

When the young plants have consumed the oxygen in the surrounding air of the thistle tube, and given off the corresponding amount of carbon dioxide, the liquid in the beaker will rise in the tube. This is because caustic potash and limewater have a strong affinity for carbon dioxide. If the liquid is colored with eosin, its rise in the tube will be more apparent.

50. HEAT FROM GERMINATION

Object. — *To find out whether germinating seeds give off heat.*

Apparatus. — Two thermometers, two flowerpots, and seeds.

Method. — Fill one flowerpot with dry seeds and the other with soaked seeds of the same kind.

Compare the thermometers to be sure that they read alike.

Thrust a thermometer into the center of each pot and stand them side by side, covering each flowerpot with a cloth to prevent evaporation, but permitting the stems of the thermometers to project above the covering.

After a few hours compare the readings of the two instruments.

Note. — A differential thermometer can be used if one is at hand and the comparative temperatures noted.

Note. — The heat in this experiment may not be entirely due to the germination of the seeds. Bacteria of decay often cause the evolution of considerable heat. If the seeds are moistened first with a solution of 5 per cent formalin and then are thoroughly rinsed off in clear water, they will be far less likely to become heated through agency of bacteria and the experiment will be more exact. For use in high schools, however, this precaution is hardly necessary.

51. EFFECT OF LIGHT

Object. — *To find out whether light has any effect upon germination of seeds.*

Apparatus. — Two tumblers, sawdust, seeds, and a dark box. To make a dark box blacken a chalk box inside with ink or paint. Cover the outside with one or two coats of black paper or cloth so that no light can enter.

Method. — Prepare the seeds by planting them in damp sawdust in the tumblers. Then put one tumbler in the dark box and the other outside. Place both on a window sill where they will receive the sunshine and move them from time to time so that the uncovered glass shall have plenty of light. Keep both tumbler and dark box close together

so that they may have the same heat conditions, and remove the box cover at night or in a closet by day so that the air supply may be ample. After three days notice the result. These seeds have had the same amounts of water, air, and heat. The only difference has been the light. Does light stimulate or hinder growth of seeds?

Conclusion. — State your inference as to the effect of light on germination.

Note. — Another method of making this experiment is to plant seeds in a pan. Invert a flowerpot over some of them, having first closed the hole in the bottom of the flowerpot. Press the rim well down into the soil to exclude light. Air will enter through pores in the flowerpot. After the seeds outside have begun to sprout, remove the flowerpot to note the difference.

52. THE FATE OF COTYLEDONS

Object. — *To find out the fate of the cotyledons.*

Apparatus. — An oblong box, soil or sawdust, and kidney beans.

Method. — Plant the beans in lots of three or four at intervals of two days, beginning at one end of the box. Set the box in a locality favorable for germination and growth. At the end of three weeks make a careful study of the crop. What has become of the cotyledons? How do the youngest plants compare with the oldest ones in size and the appearance of the cotyledons? What does this prove as to the use of cotyledons?

Conclusion. — State the results of this experiment.

53. THE FATE OF COTYLEDONS

Object. — *Same as in Experiment 52.*

Method. — Repeat Experiment 52, using squash seeds instead of beans.

Does the squash differ from the bean in the use of its cotyledons to the plant (*a*) while germinating? (*b*) later?

Does the difference in shape, thickness, and character of the cotyledon in these seeds seem to have any relation to its future use to the plant?

Suggestion. — Repeat the experiment, using castor beans and any other available seed.

54. THE FATE OF COTYLEDONS (optional)

Object. — *Same as in Experiment 52.*

Demonstration of the use of food by the young plant.

1. With a razor or microtome prepare some very thin sections of cotyledons of bean, or pea, and mount them in a drop of water under the microscope. Note the cells or compartments of which the cotyledon is built up. Note the starch grains with which these cells are packed.

Now place a drop of iodine solution at the edge of the cover glass and watch the effect as it spreads over the starch grains.

2. Make a similar section of a cotyledon taken from a seedling which has been growing for some time until the cotyledon has begun to show wrinkles. Mount it as before, examine, and again treat it with the solution of iodine. How do these cotyledons differ from the fresh ones (*a*) in plumpness, (*b*) in amount of starch in the cells? How can you account for the difference? What has become of the starch?

3. Make similar sections of the endosperm of corn and castor beans, fresh and sprouted. Use iodine solution for the corn. The oil in the castor bean needs no test to show the difference.

Suggestion. — Germinate barley or any other cereal on moist blotting paper. As soon as the first leaf begins to

appear, taste of the sprouted grain and also of an unsprouted grain of the same sort.

How do they compare in sweetness? Crush a few sprouted grains and test for starch and for grape sugar. Make the same tests on unsprouted grain. Result?

Note. — See also Note, Experiment 42.

55. EFFECT OF MUTILATION

Object. — *To learn the effect of mutilation upon growth of seeds.*

Apparatus. — Sprouting beans, peas, and squash seeds, a sharp knife, cheesecloth, tumblers, and water.

Method. — Cover several tumblers with cheesecloth, holding it fast with rubber bands or cord.

Punch three small holes through each cheesecloth cover and fill the glasses with water.

Carefully cut away one seed leaf from one seed and both seed leaves from another.

Then place the seeds upon the cheesecloth with the rootlet of each projecting downward through one of the punctures into the water. Each tumbler should have three seeds, one whole, one with one seed leaf removed, and the other with both removed. It is best to do this with at least three kinds of seeds, such as bean, pea, and squash. Continue the experiment for ten days, renewing the water from time to time as it evaporates. Note the result. Which seeds sprouted most rapidly? Which least rapidly?

Conclusion. — What is the effect of mutilation on growth from seeds?

Query. — Is the result in this experiment caused by the shock due to mutilation or to the removal of the food supply? Give reasons for your answer.

56. EFFECT OF MUTILATION

Object. — *To learn the result of removing other parts of seeds.*

Apparatus. — Same as in the preceding Experiment.

Method. — Prepare tumblers as before or fill several glasses two thirds full of damp sand and cover them with glass.

Remove the tip of the first stem (hypocotyl) from beans and peas. Carefully remove the first bud (plumule) from a bean without breaking the seed leaves apart. Cut away as much as possible of the endosperm from a soaked grain of corn or a castor bean. Then place these mutilated seeds on the cheesecloth or upon the moist sand and let them remain for ten days. Result in each case?

Conclusion. — State your inferences as based upon these observations.

VIII. GROWTH OF SEEDLINGS

57. GROWTH

Object. — *To learn how the plant comes from the ground.*

Apparatus. — Several Lima beans or kidney beans, flowerpots, soil or sawdust.

Method. — Soak the seeds and plant them and place the flowerpots in a location favorable for growth. When the seedlings begin to emerge from the soil, note their position, changes of position, etc., until the shell is cast and the first leaves are expanded. Note what parts come above ground first, also what parts remain under the surface. Illustrate all the stages by means of sketches.

FIG. 20. — Germinating beans.

Conclusion. — State briefly the steps until the first bud expands.

58. GROWTH

Object. — *To learn how the squash plant escapes from the shell.*

Apparatus. — Squash seeds, flowerpots of soil or plates covered with blotting paper and covered over with glass plates to prevent drying out.

Method. — Place the seeds in the soil in various positions or lay them upon the blotters and wet them. When they begin to germinate, note how they split the shell. What special organs are developed for splitting the shell. Does

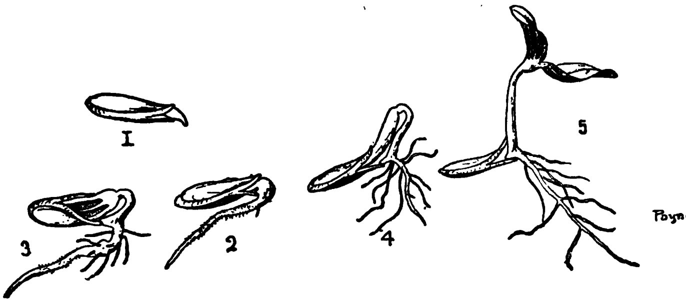


FIG. 21. — Germinating squash seeds.

the shell come up with the plantlet? If it does come up, how account for it?

Conclusion. — State step by step how the squash plant escapes from its shell.

59. GROWTH

Object. — *To learn how the pea plant comes above ground.*

Apparatus. — Peas, flowerpots of soil.

Method. — Plant peas and observe their way of coming up. How do they differ from beans? squash? Why do they not need a peg to help split open their shells? By what structure do they break ground? Of what advantage is the arch to the pea plant? Compare the size of the first bud with that of beans and squash.

Conclusion. — State how peas come up, telling what part breaks through the ground.

60. GROWTH

Object. — *To learn how a corn plant comes up through the soil.*

Apparatus. — Corn, flowerpot, and soil.

Method. — Plant the corn as in the preceding Experiments. After a few days observe how this plant forces its way through the soil and into the air.

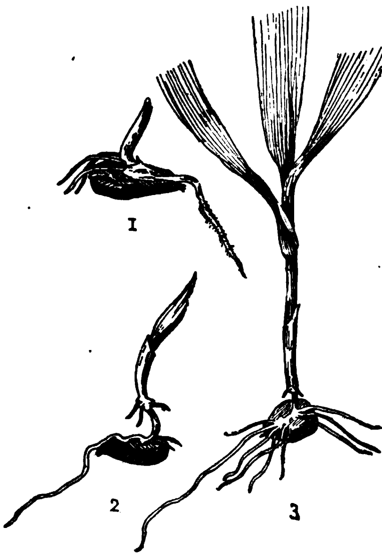


Fig. 22. — Germinating corn.

Conclusion. — State the result of your observations.

Note. — The preceding four Experiments have been introduced to illustrate three ways or types characteristic of dicotyledonous plants, and one way in which monocotyl plants come forth from the soil. Thus the squash develops an *arch* and *peg* by which it forces the shell open. The peg holds down the shell, and the arch breaks through the soil. The bean has no peg, but the arch breaks ground, dragging the cotyledons up backward. In the pea we find the cotyledons remaining underground since they can never function as foliage, and the ground is broken by a very small arched plumule. In corn and most other monocotyls there is no arch, but the plumule consists of a leaf rolled up so closely as to be able to puncture the soil. The onion seed, however, forms a fine arch in germinating.

Suggestion. — From visits to the woods, parks, or gardens in early spring find out to which type of dicotyledons each

of the following belongs: the beechnut, peach pit, acorn, chestnut, horse-chestnut, pine, and maple.

Suggestion. — Plant onion seeds on wet blotting paper and observe their interesting germination.

Plant an assortment of seeds in pots of different soils studied in the soil experiments. Is there any difference in the time required for seeds in different soils?

Plant fresh date seeds and compare their germination with cereals and other monocotyledonous plants.

Visit a conservatory and look for germinating coconuts, Brazil nuts, and vegetable ivory nuts. Some of these plants are exceedingly interesting in their early growth.

61. GROWTH

Object. — *To show that the young plant exerts force in coming up.*

Apparatus. — Seeds, flowerpots of soil, covers of baking powder boxes or other small trays, and a quantity of shot.

Method. — Plant the seeds three inches apart and place over each a tray or tin box cover containing shot. Vary the number in different trays and let the flowerpots stand for several days. Do the young shoots lift all the trays? Account for this result. What happens if the weight is too heavy to lift?

Conclusion. — Inference from this experiment.

62. GROWTH

Object. — *Same as in Experiment 61.*

Apparatus. — Small vial, shot, large glass, and a seedling just breaking through the ground. The vial should be small enough to slide easily in the glass tube.

Method. — Place the tube around the sprouting plant. Then insert the vial and add the shot. Mark the vial at the top of the tube and watch for upward motion. Vigorous seedlings will often be able to lift many times their own weight.

FIG. 23.

Conclusion. — Same as preceding.

Suggestion. — Compare seedlings of pea, bean, squash, etc., to determine which are strongest.

63. GROWTH

Object. — *To show the effect of light.*

Method. — (*a*) Plant two potatoes in flowerpots containing soil. Place one flowerpot in the light and the other in the dark. Leave them for several days. Then place them side by side. Observe the growth of the plants node for node.

(*b*) Plant potatoes, sweet potatoes, or beets in battery jars or tumblers of water so that the lower surface dips down into the water. Place some in darkness, some in shade, and others in the strong sunlight. Result?

64. GROWTH

Object. — *To study the effect of light on direction of growth of roots.*

Apparatus. — Mustard seedlings, a cork disk, and a tumbler.

Method. — On a cork disk which has two or three perforations arrange some mustard seedlings so that their roots pass through the holes. Float the cork disk in the glass of water and set it in a light place, but not in the direct sunlight.

After a day or two observe the plant and discover what the positions of stem and root are with reference to the light. How does the stem differ from the root as to its direction of growth?

Conclusion. — State the result and the probable cause.

65. GROWTH

Object. — *To find out what happens if a plant meets with an obstacle in the path of its growth.*

Method. — Place bits of stone, wood, etc., where they will interfere with the growth of (*a*) roots and (*b*) stems.

Suggestion. — This can be easily done by placing the seedlings on damp blotting paper covered with plate glass. The obstacle and the plant can thus be plainly seen at all times.

Note. — See also Experiments 158, 159, 160, 161, on plant movements due to contact.

66. GROWTH

Object. — *To study the rapidity of growth.*

Apparatus. — The auxanometer is an apparatus designed to show the rapidity of growth of a plant.

A simple form of this device is shown in Figure 24. It consists of an upright fastened to a block for support. At the top an arm extends in a horizontal direction and to it is attached a quadrant which may be cut from white cardboard and marked off into ten or fifteen equal parts. At the center of the quadrant is a pulley which may be made of a cork centered on a stout pin about which it can freely revolve.

To the pulley a wire index is fastened. A cord is tied about the stem of a plant very near to the terminal bud. This cord passes over the pulley and is held taut by a weight which is just heavy enough to move the pointer. Set the pointer at zero.

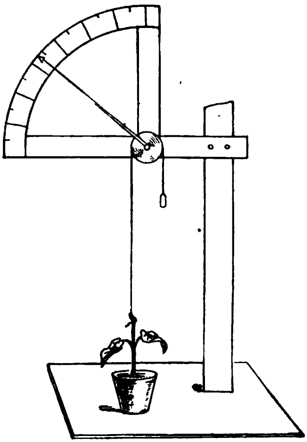


FIG. 24. — Auxanometer.

As the stem elongates the weight will drop, pulling the pointer upward as the pulley revolves. If properly adjusted, a very slight growth of stem will be indicated by a rise in the pointer.

Query. — What effect has fertility of soil on growth? What effect does water have on growth? How do plants of desert regions compare in size with those of moist regions? Why are mountain plants diminutive in size, while lowland plants of the same kind grow to greater size?

IX. SEED TESTING

Seed Inspection

It is very useful to the farmer and gardener to know how to test seeds in order to find out which are best for planting. In this way the purchase of poor seed can be avoided.

When buying for planting, one does not wish any other kinds of plants growing in the crop. "Tares among the wheat" are proverbial, and mixtures of different varieties of the same plant often render a crop unfit for market.

In grain elevators, mills, and malting houses great care is taken to remove all foreign substances.

67. PURITY

Object. — *To determine the purity of a given sample of seed.*

Method. — Examine the seeds in bulk, taking note of the presence of foreign matters, such as dirt, chaff, leaves, chips, and other kinds of seeds.

Measure out equal bulks of each sample under inspection and sift them with a sieve having a smaller mesh than the size of the seed. Dirt, dust, and much of the other impurities will be removed in this way. Now spread the seeds evenly over the bottom of a shallow tray or plate.

Compare the different samples. Which has most dirt? Which shows the greatest amount of other impurities? Which is best for planting?

68. WEIGHT

Since the amount of food stored in a seed determines the vigor and hardiness of the plant, weighing is an important test in determining the value of seeds.

Object. — *To determine the weight of a sample of seeds.*

Method. — Weigh out equal quantities of different seeds under inspection, having first removed any impurities. Count the seeds in each portion. The sample showing fewest seeds to a given weight will be the best.

Another method is to pick from each sample one hundred seeds and carefully weigh them.

Note. — Weight is not always proportional to size. Large seeds are sometimes found in which the kernel is missing or shrunken to very small size.

69. COLOR AND ODOR

Object. — *To study the color and odor of seeds.*

Young seeds are of a bright, fresh color. Old seeds lose their freshness and become dull colored, sometimes fading and sometimes becoming darker in hue. Most fresh seeds have an agreeable smell and some are truly aromatic. But with age the oils in seeds are apt to become rancid, and so there is often a disagreeable odor about old seeds. Damp seeds also acquire a musty odor.

Method. — Procure various samples of fresh seeds. Compare them with old seeds of the same sort, noting the difference in color and brightness as well as the difference in odor.

Plant old and new seeds of the same sort under conditions favorable for germination. Result?

70. FORM

Seeds which have developed symmetrically are the best growers. A seed which has been hampered or stunted in its growth is handicapped owing to its lack of food or its deformed embryo.

Object. — *To learn whether form has any effect on germination of the seed and growth of the plantlet.*

Method. — From an ear of corn select grains which grew at the ends where they are misshapen. Select also the same number of perfectly formed kernels from near the middle of the ear. Plant both sets under conditions favorable for germination. Which kind are first to start? From which kind do the largest number germinate? Which ones put forth the healthier growth? After a month's time which plants look most vigorous?

71. GERMINATION CAPACITY

Object. — *To study germination capacity.*

The following exercise is modified from Circular 96, U. S. Department of Agriculture, 1910.

Method. — Make a shallow box about 2 inches deep and about 23 × 15 inches. Fill it with sand, sawdust, or soil. Then by means of twine lay it off into squares like a checker board, making ten on the end and fifteen on the side. This is the germinating tray. Choose ten ears of corn and number them to correspond with each of the ten rows in the tray.

From each ear remove five kernels from each row, rejecting kernels from the ends of the ears, and selecting those in a spiral around the ear.

Plant the kernels in the row which represents the ear from which they came. Push each kernel, point downward, just far enough to be covered with soil and arrange them so that there shall be one near each corner and one in the center of each square. Saturate the tray with water and place it in a warm place, keeping the plants moist until they are one inch tall.

Examine the squares in regular order, noting, (*a*) the number of seedlings in good condition, (*b*) the number in poor condition, (*c*) the number of squares in which there were no seedlings, etc. (*d*) If any seedling failed to come up, carefully remove the sawdust and find out the cause.

Tabulate the results.

72. PERCENTAGE OF GERMINATION

Object. — *To learn the percentage of germination.*

Method. — Make a seed tester by cutting several pieces of flannel, felt, or blotting paper to fit a dinner plate.

Sterilize the cloths by boiling them in water for five minutes and arrange them as follows: —

Place a layer of cloth on the plate. Lay one hundred soaked seeds upon it. Cover them with another cloth and lay a pane of glass or an inverted plate over it. Remove the cover from time to time to aërate the seeds and at the same time remove all seeds which have begun to germinate. When no more seeds will germinate, count the number of ungerminated seeds and subtract it from the original number, 100. This will give the percentage of germination. Thus if 15 out of the hundred failed to germinate, the percentage of germination would be 85.

73. GERMINATION SPEED

Object. — *To study germination speed*

If in Experiment 72 the number which germinate *each day* is recorded, and these results tabulated, it will be possible to determine the relative speed of germination. In choosing seeds for planting those which are quickest to germinate are most to be desired, since the earlier the crop, the better will be the market price.

Method. — Procure packages of garden seeds, such as radish, turnip, lettuce, cucumber, melon, peas, beans, and cereals. Get them from different seedsmen and farmers. Test them to determine their speed, capacity, and percentage of germination.

Query. — Why is it preferable to buy seed corn on the ear? Why are high-priced seeds not necessarily the dearest? Why is it not safe to plant seeds left over from past years?

Vitality of Seeds

Plant seeds from immature fruits, using apples, cucumbers, squashes, pea pods, etc.

Plant seeds which have been a long time in bottles. Keep a record of the number which are planted and the number which sprout. Result? Inferences?

Reference Work on Seeds

The following questions are inserted here as suggestive of what may be done by pupils in finding out facts relating to seeds.

How are seeds collected by the farmer for future planting? How is a granary or corn crib built and why is it constructed as it is? How is grain harvested? How shipped?

How is grain loaded and unloaded at mills and grain elevators? How is it elevated? How cleaned? How weighed and bagged? What impurities are found in grain? Describe the construction of a grain elevator.

How is grain ground in a mill? What is the object of grinding? Of bolting? How does stone milling differ from the roller process? Describe the bolt. How does bolting cloth differ from other cloths? Where made? Name some products made in a mill. What are bran, shorts, middlings, Graham flour, gluten? Name some of the breakfast foods made from wheat, corn, oats, barley, etc.

What is malt? How is it prepared? What change takes place in the grain during the malting process?

What ingredients enter into the process of brewing? How is beer manufactured? Of what use is yeast in the process? (See Experiments 214–220.) Why? For what are hops used? Where do they come from?

What liquors are made from rye, barley, corn?

X. ROOTS

Root Structure

Suggestion. — Prepare a number of bean, pea, and corn seedlings by carefully digging them up and washing away any clinging soil particles; or use a pocket garden. Find the long main root (*primary root*). Of what is it the continuation? What is its normal direction of growth? Find the other roots (*secondary roots*) which branch from the primary root. What is their normal direction of growth? Account for the difference in direction between primary and secondary roots. Find other branches (*tertiary roots* or rootlets). What is the general direction of all the roots? Is there any definite system of arrangement in the branching of roots? Have they any definite shape? Do they seem to be limited in the length to which they grow? Look for root hairs near the ends of young roots. Do they occur at the very tip of a root? Are they seen along the surfaces of old roots?

74. ROOTS

Object. — *To find out the parts of a root.*

Apparatus. — A parsnip or carrot, and a sharp knife.

Method. — Examine the root, first giving attention to the external appearance. Afterward make sections lengthwise through the center and crosswise at different points so as to see the gross structure.

1. *Outside examination.* Describe the outer covering (epidermis or skin). What is its color, texture, thickness, and general appearance? Find the bud. Where is it located? Of what is it composed? Find the depressions which are found on the surface. Is there any system in their arrangement? What is seen projecting from some of these depressions? (Secondary roots.)

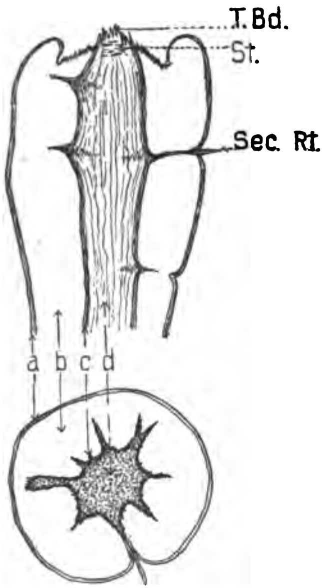


Fig. 25. — Structure of a parsnip root: *a*, skin; *b*, cortex; *c*, sap region; *d*, central cylinder; *T. Bd.*, terminal bud; *St.*, stem; *Sec. Rt.*, secondary root.

2. *Interior examination.* Of how many regions is the parsnip composed? How does the central portion (central cylinder) compare in color and structure with the part underlying the skin? (Cortex.) What separates the cortex from the central cylinder?

Make very thin cross sections and look through them towards the light. Can you discover any system in structural arrangement? When possible, compare a parsnip two years old with one of one year.

Cut sections through the parsnip at the point where secondary roots are given off. Where is the origin of a secondary root? Draw outside view, longitudinal and cross sections.

Conclusion. — Name the parts of a root and state where each is located with reference to the others.

75. ROOTS

Object. — *To find out where the sap circulates in a root.*

Apparatus. — Two large parsnips, a battery jar, and a pint of water in which a small quantity of eosin has been dissolved.

Method. — Cut off the tip of one parsnip and place it standing in a jar containing eosin solution. Let it remain for two or three hours. Then remove it and make a section from end to end. What region of the root has become stained?

Dig out a cuplike hollow in the top of another parsnip and fill it with eosin solution and let it stand. After three hours rinse out the top and make a section as before.

Does the sap circulate both ways or only one? In which region?

Conclusion. — State where sap flows in a root.

Note. — If anilin of two colors is used, one color in the battery jar and the other in the cuplike hole at the top, it will be seen that the upward and downward circulation is not in the same set of tubes.

Beautiful sections can be made by using eosin and methyl green as the anilin dyes.

To the Teacher.—If parsnips are treated in this way and then sliced very thin on an ordinary cabbage cutter or with a carpenter's plane, they may be dried under pressure between blotters and then mounted between plates of glass and bound with passe partout binding. Such mounts are useful in demonstrations and reviews.

76. ROOTS

Object. — *To learn the direction of growth in a root.*

Apparatus. — A plate of glass, blotting paper, germinated seeds.

Method. — Arrange the sprouting seeds upon a blotter so that the roots point in the same direction. Cover them

with the plate of glass and bind with cord. Keep the blotter damp and hold it in the original position until the roots are a half inch long. Then turn the plate over on the side so that the roots point in a horizontal direction. Observe them from time to time. Do the root tips show any response to the change of position? How? (Fig. 26.)

Fig. 26.

After a day or two turn the apparatus again on the next side. Continue turning the plate as the roots continue to grow.

Conclusion. — In what direction do roots grow? Can you give a probable reason?

77. ROOTS

Object. — *Same as in Experiment 76.*

Apparatus. — Bell jar, shallow pan, cork float, pins, seedlings, and water.

Method. — Fasten two or three seedlings of equal size by pins as in Figure 27, so that the sprouts point upward. After a few hours note the change of direction of growth.

Note. — The bell jar is used to keep the seedlings in a moist atmosphere.

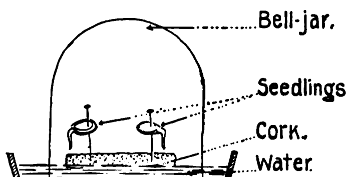


Fig. 27.

78. ROOTS

Object. — *Same as in Experiment 76.*

Method. — Prepare a box of soil in the center of which is placed an ordinary porous flowerpot having the hole in the bottom closed with a cork, and filled with water.

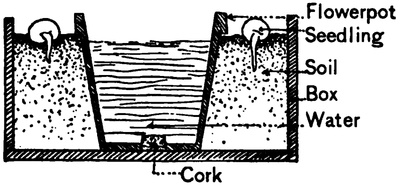


FIG. 28.

Plant seeds in soil a few inches from the flowerpot. The only moisture in the soil is what comes through the pores of the flowerpot.

After three or four days carefully remove a seedling and note the direction in which it has grown.

Query. — Downward growth in ordinary earth is probably due to what?

79. ROOTS

Object. — *Same as in Experiment 76.*

Method. — Arrange a cone of wood or a funnel as in Figure 29. Fill the funnel with wax or paraffin and cover it with a layer of blotting paper. If the cone is of wood or wax, the paper may be fastened with a pin or thumb tack.

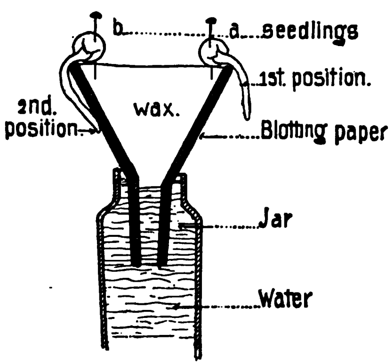


FIG. 29.

Stand the cone in a vessel of water so that the lower edge of the blotting paper will be below the surface of the water, in order that the whole paper may be kept moist.

Select seedlings whose roots are about $\frac{1}{2}$ or $\frac{3}{4}$ of an inch long, and place them as in *a* so that the root will project outward.

Stand the whole apparatus in a shady place for a day or two and then examine it. Account for this change of position in the root.

Note. — Sachs has shown the turning towards water (hydrotropism) by an experiment like the following.

80. ROOTS

Object. — *Same as in Experiment 76.*

Method. — Prepare a box with a wire-netting bottom. An ash sieve will do very well. Scatter sprouted peas all over the netting. Fill the sieve with wet sphagnum moss or other similar substance and suspend it in an oblique position. The roots which project downward will soon show a tendency to bend upward towards the wet moss.

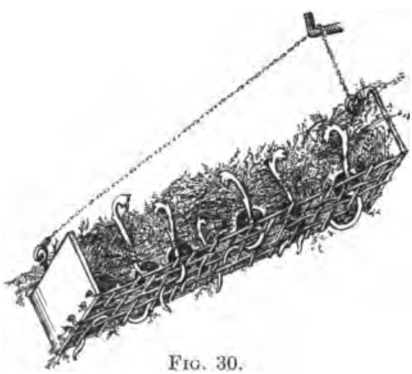


FIG. 30.

They will frequently be found weaving themselves in and out among the wires of the screen.

The root seems to be endeavoring to obey two influences: one, geotropism, which draws it earthward; the other, hydrotropism, which causes it to turn towards the water supply.

81. ROOTS

Object. — *Same as in Experiment 76.*

Method. — To show how a root obeys both gravity and water in its direction of growth, place a triangular piece of wood small end downward. Cover it with several layers of filter paper and saturate it with water. Fix a young seedling as in Figure 31 so that its roots hang down.

Leave it standing for a few hours and note change of direction.

Make a sketch to show original position and with a dotted line indicate any change in direction of the root.

Note. — See also Experiments 42 and 64.

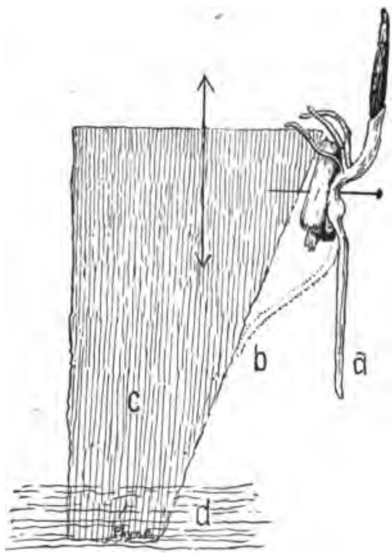


FIG. 31. — *a*, root in original position: *b*, root in new position; *c*, wood; *d*, water.

Geotropism

It has been demonstrated in several experiments that roots of a plant have a more or less definite tendency to grow downward. This property is known as *geotropism.*

We say that roots are *positively* geotropic when they grow downward towards the earth's center.

Stems may be *negatively* geotropic when they grow upward or away from the earth. Stems which creep or lie

prostrate, and secondary roots which extend outward from the main root, are said to be *neutral*, since they show neither positive nor negative geotropism.

Many interesting experiments may be devised by the use of an apparatus called a clinostat. This is a revolving support run by clockwork, and capable of being made to rotate at any angle.

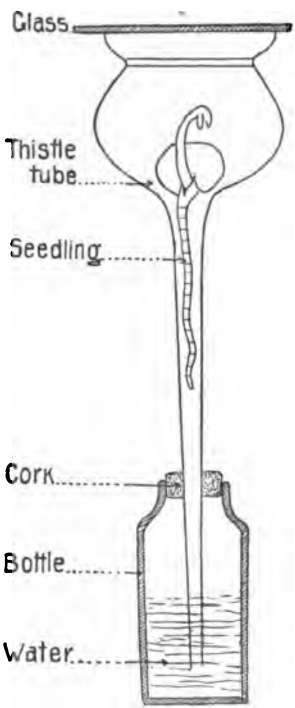


Fig. 32.

82. ROOTS

Object. — *To measure the rapidity of growth.*

Method. — Arrange a thistle tube or funnel as in Figure 32 and place a seedling in position.

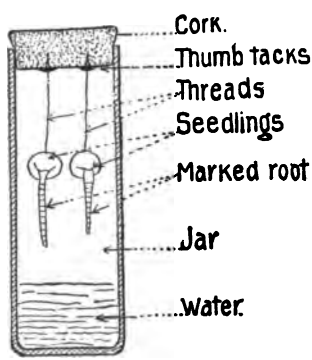


Fig. 33.

As the sprout pushes downward, mark its termination from time to time by thread or mucilaged markers.

If conditions of heat, light, etc., are varied, the effects of these agencies upon rapidity of growth can be noted and measured.

83. ROOTS

Object. — *To determine just where growth in a root is most rapid.*

Method. — Arrange an apparatus as in Figure 33, suspending the seedlings by means of thread and marking the young roots with the marker shown in Figure 38. After a few hours examine the roots and discover whether the lines are equally distant as at the start.

Where is the growth most rapid?

84. ROOTS

Object. — *To show that roots give off acid in growing.*

Apparatus. — As shown in Figure 34.

Method. — Fill the lower part of a funnel with gelatin in which a little blue litmus solution has been dissolved. When it has cooled enough to become firm below, insert the root of a seedling. Cover the funnel with a glass plate and stand it in a rack or bottle. After a day or two note the change in the color of the litmus. What does this prove?

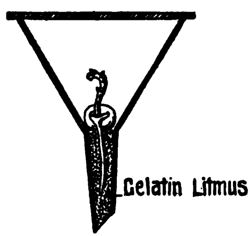


FIG. 34.

Suggestion. — Place young seedlings upon damp blue litmus paper. Result?

Suggestion. — Place a slab of polished marble in a flowerpot so that it is inclined towards the top. Lay a grain of germinated corn or other seed near the top so that the roots when they grow will lie upon the polished surface of the marble.

Now fill the flowerpot with soil, and water it well.

When the plant is full grown and shows sign of dying, remove the marble slab and plant together, shaking off the soil and washing the slab with clear water. An etching will often be found showing where each tiny rootlet touched the marble.

Account for this.

Prints of such an etching may be made by coating the slab with a mixture of vaseline and lampblack and applying the slab to paper.

Examine surfaces of rock over which roots have grown. How can we account for the grooves in which such roots lie?

85. ROOTS

Object. — *To observe the production of adventitious roots.*

Apparatus. — A bottle, water, a branch of willow, poplar, ivy, oleander, or tradescantia.

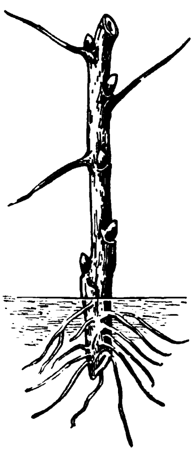


FIG. 35. — Adventitious roots in water.

Method. — Cut the branch with a sharp knife and put it into the bottle full of water. As the water evaporates add more. When roots appear, note where they grow, also the character of such roots and the root hairs which cover them.

Repeat the same experiment, using leaves instead of branches. The leaves of English ivy and rubber plant are specially good. The top of a pineapple cut off and placed on top of a vessel of water so that the under surface is wet will produce roots in this way.

Conclusion. — How may adventitious roots be made to appear?

86. ROOTS

Object. — *To learn how plants may be propagated by cuttings.*

Apparatus. — Branches of plants named in the preceding Experiment, also geranium, fuchsia, or begonia. Flowerpots of clean, sharp sand.

Method. — Make the cuttings with a sharp knife. Remove nearly all the leaves. Thrust each branch into a flowerpot of sand. Dampen it, cover it to prevent drying out,

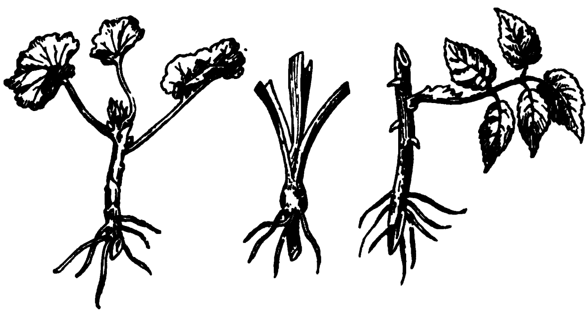


FIG. 36. — Rooted cuttings.

and set it in the shade for one week. Remove one cutting and examine it. Look for a scab or callus where the cut-off end is healing. Examine the cuttings from day to day to study the formation of roots.

Conclusion. — How may plants be propagated by cuttings?

Query. — Of what practical value is this knowledge? Of what commercial importance is this to the florist and gardener?

87. ARTIFICIAL PROPAGATION

The propagation of plants by cuttings was presented in the previous Experiment. There are other ways of producing plants artificially.

Object. — *To learn how plants may be propagated by layering.*

Method. — Select a shrub growing in the garden. Rose bushes and currant bushes are good for the purpose. Choose a long branch which can be bent over without breaking and remove a portion of bark from the lower side where it will touch the ground.

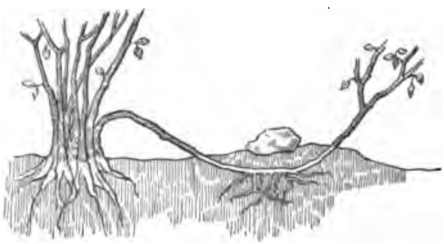


FIG. 37. — A layer.

Lay the wounded surface upon the ground, put a small amount of soil upon the branch, and place a stone upon it to hold it in place. Pegs or staples may also be used for the purpose.

After a few weeks cut the connection between the layer and the parent plant. If examined, roots will be found about the wound, and the layer will have become a separate plant.

In a similar way plants may be layered from one flower-pot to another. Periwinkle, which is propagated with difficulty by cuttings, can be easily grown in this way.

Queries. — How does the creeping buttercup propagate itself?

How does witch grass spread? Why does cutting off such plants with a lawn mower not exterminate them?

How do you account for the fact that willows usually grow along streams? How does the strawberry plant spread? How does the grower of small fruits make use of this peculiarity of the strawberry plant? Examine the long shoots of a black raspberry bush late in the summer. What has taken place where these long shoots have touched the ground? Examine a plant of "Old-hen-and-chickens." How does it spread? Find out what are *runners*, *stolons*, and *offsets*. What plants propagate themselves in each way?

88. ARTIFICIAL PROPAGATION

Object. — *To learn how plants may be propagated by offsets.*

Apparatus. — Some sets of onions or the little black bulblets of the tiger lily, soil, etc.

Method. — Examine the offset. What does it look like? Plant it in a flowerpot of damp soil and cover it to prevent drying.

Conclusion. — How may onions and tiger lilies be propagated?

Note. — Late in summer examine the stems of the cinnamon vine and find the little tubers resembling potatoes by means of which that plant propagates itself.

89. ROOTS

Object. — *To discover the use of the skin to a root.*

Apparatus. — A parsnip root and a dish of water.

Method. — Allow the parsnip to lie in a warm, dry place for some time. After it has become quite soft and flexible

immerse it in the water for about an hour. Remove it and note the change.

Conclusion. — How does this experiment show that the skin absorbs water?

Note. — This exercise does not prove that all the absorbed water comes in through the skin alone. There may be holes where root branches were broken off through which the water may also enter the root.

Query. — Why do roots wilt when removed from the soil? How may they be revived? A grocer sometimes puts vegetables which have been exposed to the sun and air on his vegetable stand into a tub of fresh water. Why is this done?

To show that roots absorb water from the soil, fill two flowerpots of equal size with equal weights of dry soil. Set a plant in one. Water both flowerpots equally and set them aside in a location favorable for growth. After three or four days examine both flowerpots. Which contains the drier soil? What has become of the water? How did it escape from each?

90. ROOTS

Object. — *To discover the use of the skin of a root.*

Apparatus. — Two parsnips of nearly equal size and weight.

Method. — Carefully peel the skin from the larger parsnip until they are of the same weight.

Put them in a dry place and weigh them from time to time, or place them in opposite pans of a balance.

What change takes place in the weight of these roots? Which loses more rapidly? Why?

Conclusion. — What are two uses of a skin on a root?

91. ROOTS

Object. — *To learn how a plant increases the absorbing surface of its roots.*

Method. — Plant some radish seeds on moist blotting-paper, and when the roots appear note their surface. Examine them with a hand magnifier. Repeat the experiment, using oats or corn.

Visit a conservatory and examine the aërial roots of orchids. What takes the place of root hairs and why is this modification beneficial to epiphyte plants?

Suggestion.— Cut off a root tip of a germinating oat or radish seed, mount it in a drop of water, and examine it with a low power of the microscope. The character of a root hair, the central cylinder, cortex, and root cap can readily be made out. If a drop of eosin or methyl green is allowed to follow under the cover glass, these structures will be more easily seen.

92. ROOTS

Object. — *To find whether roots absorb water.*

Apparatus. — A wide-mouth bottle, cork, and a small plant.

Method. — Fill the bottle with water. Perforate the cork and through the perforation pass the roots of the plant. Insert the cork so that the roots are immersed in the water and put some cotton around the stem to prevent evaporation.

Does the water go down? If so, where has it gone?

Conclusion. — State the inference you can draw from this experiment.

93. ROOTS

Object. — *To find out where the water enters the plant.*

Apparatus. — A young plant having root hairs plainly visible, very dilute eosin solution.

Method. — Place the plant in the dilute eosin solution for three minutes, then wash it thoroughly in clear water. What parts become colored with the eosin?

Conclusion. — State what special part of the roots absorb.

Note. — To distinguish between root and stem in very young plants place them in weak solution of potassium permanganate. The roots will become stained dark brown by the solution, but the stem will remain white.

94. ROOTS

Object. — *To find out whether light has any effect on the growth of roots.*

Apparatus. — Two sets of seedlings, soil or sawdust, a battery jar, and glazed flowerpot.

Method. — Fill the two dishes with soil or sawdust and plant the same number of similar seedlings in each, placing them as near the sides of the dish as possible where those in the battery jar will be sure to be exposed to light.

Now put both dishes in a sunny exposure. After several days remove the seedlings from both dishes and observe the size and position of the roots.

Conclusion. — From this exercise what do you infer to be the effect of light on health of a root and direction of its growth?

Definition. — The behavior of a plant with reference to light is called *heliotropism.* Turning toward the light is

called *positive* heliotropism; the opposite is known as *negative* heliotropism.

Suggestion. — To show negative heliotropism of roots plant seedlings on cloth over water in a tumbler or battery jar. Cover the outside of the jar with black paper so as to exclude light from the roots. Make a slit or small hole through the cover paper so as to admit light at one point. Keep the apparatus standing in the same position for several days. (See Figure 40.)

Remove the cover and note the position of the root.

If the experiment has been carefully prepared, the root tip will be found pointing away from the aperture where light entered.

Suggestion. — Test carrots, parsnips, beets, radishes, turnips, etc., for starch, cane and grape sugar, and protein. Which are richest in starch? in sugar? Why do we eat radishes raw, while potatoes must be cooked?

Separate some of the cortex from the central cylinder of several roots and test each tissue separately for the various nutrients. From the results of such tests what do you conclude is the principal place of food storage in roots? Is there any relation between the size of a root and its food contents?

Reference Work. — Find out how beet sugar is obtained, tracing the process from seed time to the manufactured product.

95. ROOTS

Object. — *To learn the effect of nutrient solutions upon the growth of young plants.*

Directions. — Select two young cabbage plants about three or four inches tall and place them in two bottles,

suspending them by means of cotton wool, so that their roots shall dip below the surface of the liquid in each bottle.

In one bottle place distilled water or rain water; in the other soil water. The latter may be obtained by thoroughly mixing common rich garden soil with water and allowing it to stand until all sediment has settled and the water has become clear.

Place both plants for some time in a locality favorable for growth. After a few days or even hours note any difference in appearance of the plants.

Which is the more vigorous in its growth? Why?

Replenish each bottle with the kind of water which belongs in it, and note the result after several days.

Note. — If rain water is used, it should not be taken from cisterns or rain barrels, since roof drainage frequently contains mineral and organic matter which has gathered as dust on the house tops. If distilled water is not at hand, melted artificial ice is an excellent substitute.

96. ROOTS

Object. — *Same as in Experiment 95.*

Method. — Repeat Experiment 95, using various solutions of saltpeter, making the solution in one bottle very weak and the others much stronger.

After a short time examine the two plants. What has been the result? If several such bottles are arranged, the first containing distilled water only, the second having but a drop of saltpeter in it, the third, fourth, and fifth having greater amounts, the results will be more definite. This will explain why the farmer does not give too much fertilizer to his plants.

97. ROOTS

Object. — *To discover why strong fertilizers are harmful to plants.*

Apparatus. — A potato, water, a knife, and saltpeter.

Method. — Cut the potato into thin slices. Make a strong and a very weak solution of the saltpeter. Put some slices of the potato into each solution and leave them for an hour. Then remove them and examine them. How do they differ? Why?

Explanation. — The weak solution, being good for the plant, can be absorbed through its walls by osmosis; but the strong solution, being in need of more water, absorbs it from the plant, so that the latter *loses* water instead of taking it up.

Note. — With very strong solutions there seems to be a sort of toxic effect.

Field Work

98. COMMERCIAL FERTILIZERS

Object. — *To study the effect of fertilizers.*

Method. — Procure samples of as many different fertilizers as possible and apply them as follows: —

Plant as many plants as there are fertilizers and an extra one for control.

Treat each plant with one sort of fertilizer, being careful to label each plant so that no mistake will be possible. Observe the growth during the season and compare results.

Are all fertilizers equally good for all crops? In all soils?

Talk with farmers and gardeners to find out what kinds of fertilizers are best for each of the following crops: corn, potatoes, tobacco, and wheat.

What is done with soils which are too acid? Too alkaline?

99. ROOTS

Object. — *To study the effect of heat on the action of roots.*

Method. — Set a potted plant in a dish of ice water and another of the same size in a dish of warm water so that the flowerpots are immersed. Young radish, cabbage, tomato, or coleus plants will do very well. Keep both plants in a warm room where all other conditions are alike.

After an hour or two examine both plants, observing all parts. How do they differ in appearance? Now reverse the plants, placing the cold one in the warm water and the other in the ice water.

After another two hours again observe the plants. Result?

Conclusion. — State what may be inferred from this experiment as to the most favorable conditions for root action.

100. ROOTS

Object. — *To show the effect of mutilation of roots on the growth of the plant.*

Method. — Young cabbage or celery plants will do very well. Transplant two seedlings about four inches high into flowerpots of the same soil. With the first plant take care not to injure the roots and press the soil carefully around them. With the second plant grasp the stem carelessly between the fingers and merely pull it up; put it into the flowerpot and scatter soil on the roots. After one week compare the two plants. How do they differ? Why?

Note. — To prevent mutilation of roots seeds are sometimes planted in egg shells filled with soil. They can be transplanted without being dug up. The shell and all may be planted in the ground, and thus the roots will not be disturbed.

101. ROOTS

Object. — *To study plant foods.*

It is a well-known fact that plants will not thrive indefinitely in the same soil: —

1. The plant takes up from the soil those substances which it needs for its nourishment so that in time the soil becomes impoverished through loss of the food elements which it originally contained.

2. The presence in the soil of harmful bacteria may render it unfit for the growth of certain crops.

3. The presence of poisonous excreta which have been thrown off by previous crops.

The loss of food content is by far the most important of these causes of sterility of the soil.

The farmer, the gardener, and the florist meet these conditions in several ways.

(*a*) *Repotting and transplanting.* When a plant shows by its growth that it has exhausted the food supply in its soil, it can be carefully removed from the flowerpot and repotted into a larger one with a supply of fresh soil. It can likewise be removed to another locality where the soil has not become impoverished. But there is a better method known as (*b*) *fertilizing.*

A fertilizer is any substance which contains materials suitable for plant food. They may be of *mineral* origin, such as phosphate earth, lime, plaster, or Chile saltpeter; or *vegetable* matter, such as decayed vegetation, wood ashes, or green growth plowed under; or they may be *animal* matter, such as bones, sea shells, guano, and waste from stables.

(*c*) *Nutrient solutions* are often made up, consisting of

various chemical salts dissolved in water. These are the best for experimental purposes. A good nutrient solution may be made by using the following formula: —

Calcium nitrate	6 g.
Saltpeter	1½ g.
Epsom salt	1½ g.
Neutral potassium phosphate . . .	1½ g.
Common salt	1½ g.

Dissolve the above in 600 cc. of distilled water and keep it in a corked bottle in the dark.

When it is desired for use, shake it thoroughly and dilute 10 parts to 48 parts of distilled water.

To prove the value of the solution try it on seedlings, cuttings, and potted plants. Prepare three tumblers as follows: (*a*) full of distilled water, (*b*) full of well water or hydrant water, and (*c*) full of distilled water, into which the nutrient solution has been added according to direction (10 parts to 48 of water).

Now carefully place some seedlings which have been sprouted on blotting paper or cloth upon a cork float and fasten them with a bit of cotton batting so that their roots can be wet with the contents of the tumblers. Arrange three sets of seedlings, one in each glass.

After a week which seedlings are growing best? Why?

Repeat the preceding exercise, using cuttings of willow, poplar, or tradescantia which have been previously rooted in water.

Water two potted plants of about equal size at the same time every day, giving to one only distilled water and to the other equal portions of a nutrient solution.

How do they compare in size, number of leaves, etc., at

the end of a month? What must be inferred from the results of this experiment?

Origin of Some Fertilizers

1. The commonest fertilizer in use is stable manure. It is prepared by piling in heaps, where a sort of fermentation takes place. When the mass has been reduced to a dark color and heat has ceased to be generated, it is ready for use.

2. Guano is a fertilizer imported from the rocky islands on the Pacific coasts of South America. It consists of bird manure, eggs, bones, decayed remains of fish, birds, etc., which have accumulated where the birds have their breeding grounds. It resembles a grayish black soil and is a very rich fertilizer.

3. Phosphate earth is classed as a mineral fertilizer, but it is in reality of animal origin, being composed of the fossil remains of fishes and other animals of long ago. The phosphate beds of the Carolinas are the principal source of this fertilizer.

4. Chile saltpeter is a mineral found in many parts of the earth, where it is mined. The greatest exporter of this substance is Chile, hence the name.

5. Wood ash, although obtained from plants, is a mineral substance. It is rich in potash.

6. Lime is not itself a plant food, but it owes its chief value to the fact that it decomposes many organic substances, causing them to give up ammonia, which is a valuable fertilizer. If a little lime is put into a test tube together with any animal substance and heated, the familiar odor of ammonia will be quickly detected.

A good nutrient solution for plants may be made by mix-

ing a small quantity of hen manure with two or three hundred times as much water.

Stir it well and let it stand. From time to time, dip off water from the top and use it for watering plants. As the water is used up add more. This has been found to be an excellent plant food, but it should not be used too frequently or too strong.

XI. STEMS

102. LOCATION OF GROWTH

Object. — *To find where young stems grow most rapidly.*

Apparatus. — Young seedlings of bean, pea, squash, or any other young shoots, a marking apparatus as shown in Figure 38. It is cut out of pine and has threads stretched across it exactly one eighth of an inch apart.

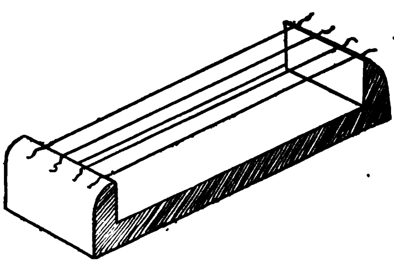


FIG. 38. — Growth marker.

Method. — Wet the threads of the marker with India ink and touch the young stem. This will make a series of lines or dots on the stem one eighth of an inch apart.

After a day note whether the dots are the same distance apart. Continue to make observations, until you know where growth is most rapid. (See also Experiment 82.)

Conclusion. — State the result of this experiment.

103. UPWARD GROWTH

Object. — *To learn something of upward growth of stems.*

Method. — Plant a seedling in a flowerpot so that it projects through the drain hole. Then suspend it as in Figure 39. After a few days observe the position of the stems.

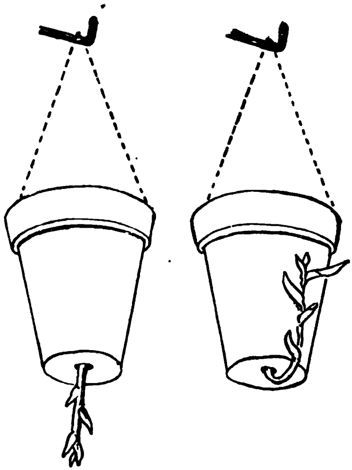


FIG. 39.

Sketch. After a week or two carefully remove the plant and notice whether the root growth has been affected.

Query. — Why do corn, wheat, etc., tend to straighten themselves when they have been blown over by the winds? How do you account for lopsided trees which grow at the edge of a forest?

Why are the young trees in the forest so tall and slender?

104. STEMS

Object. — *To study the effect of sunlight on the growth of stems (heliotropism).*

Apparatus. — A dark box having one small hole for admission of light, seedlings in a small flowerpot.

Method. — Place the plant in the dark box and leave it there for several days. Notice the effect of darkness on color and size of the stem. Observe the direction in which the stem grows.

Compare a plant grown in the dark with one of the same sort grown in the light. How do they differ in length, color, size of the leaves, distance between leaves, etc.?

Conclusion. — State in three sentences what you have learned by this experiment.

Suggestion. — Place a potato in a glass of water so that the under side is moist; set it on the window sill where there

is plenty of light. After the eyes have sprouted compare it with another potato which has been sprouted in a dark cellar.

How do you account for the difference?

105. STEMS

Object. — *Same as in Experiment 104.*

Method. — The growth of root and stem in obedience to light and gravity may be shown by arranging an apparatus like the one shown in Figure 40. First arrange a seedling as in (*a*), having the roots immersed in the water of the test tube.

Wax well about the top to prevent the water from coming out.

Then invert the apparatus and fasten it in a clamp.

Observe the directions taken by root and stem (*b*). If placed where the light comes from only one side, notice the directions in which both stem and root turn.

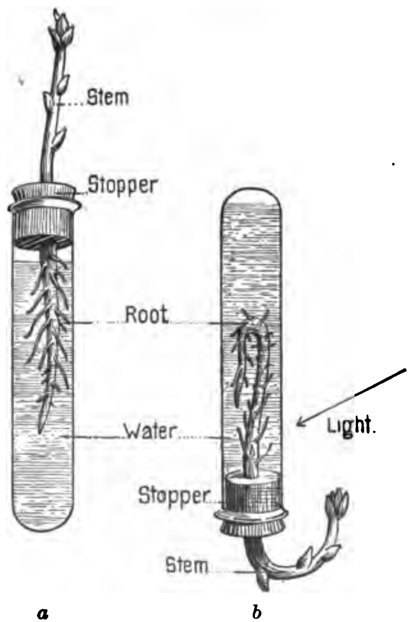


FIG. 40.

Conclusion. — What do you infer from this as to the effect of light on direction of growing roots and growing stems?

106. STEMS

Object. — *Same as in Experiments 104 and 105.*

Method. — Prepare two sets of seeds by letting them germinate in a box of good soil.

As soon as the sprouts peep above the soil, place the box in a position where heat, water, and air supply will be favorable for growth, but not in direct sunlight. Now cover some of the plants by placing over them an inverted flowerpot whose drain hole is corked tight. Push the flowerpot down far enough to prevent any light from getting in below. The plants will thus be placed in exactly similar conditions except light.

From time to time examine and measure length of nodes and size of leaves. Note also the color of stem and leaves, and the vigor of stem. Remove the inverted flowerpot and expose the plants to the light.

After three days look for changes in color, vigor, etc.

Turn over a flat stone or board which has lain for some time on the ground. How have plants been affected where light was excluded?

Note. — The preceding exercises are equally good to demonstrate the effects of light on roots.

Suggestion. — Cut off a stem of wheat or any other cereal long enough to have at least one node. Pass it through a cork into a flat bottle partly full of water and lay the bottle on its side so that the cut end of the stem is under the surface of the water. Stand the whole in a dark place for several hours. What is the result? Why?

For city schools any of the common tall grasses found growing in waste places are equally good for this work.

107. STEMS

Object. — *To discover the parts of a typical stem.*

Apparatus. — Portions of several different kinds of stems, such as bamboo, Indian corn, maple, lilac, ailanthus, or beech.

Method. — Select the portion of stem included between the leaf scars of any two consecutive leaves.

Study this region carefully and make out such facts as color, texture, surface, covering, and appendages, such as hairs, prickles, etc., if they occur. Find a node (joint). What structures are found at a node? Do you find these organs elsewhere than at the nodes? (See butternut, cherry, and bitternut.) Measure the length of an internode (space between two consecutive nodes). Do the internodes vary in length or are they about the same in length?

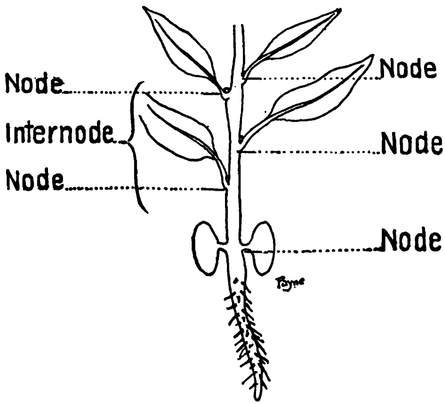


Fig. 41.

Now select another part of the same branch and examine the same portion. Do the nodes and internodes sufficiently resemble each other as to be recognized as being taken from the same plant?

Of how many internodes does the branch you have consist?

Study each of the other branches as you did the first.

Do they have nodes? How many leaves to each node? How many axillary buds to each node? How does maple resemble lilac? How does maple differ from ailanthus and beech? Which plants have prominent nodes? Which have least conspicuous nodes?

Conclusion. — Of what unit does every stem consist?

Note. — A stem may be considered as being made up of the sum total of its nodes and internodes. The unit of plant gross structure is the internode with one node.

Note. — When a seed is dissected, its embryo is found to consist of a single internode (the hypocotyl) and one node bearing one or more seed leaves with a growing point (the plumule) between them.

Growth therefore consists of the multiplication of these units as the plant is built up.

Gross structure is resolvable into internodal units, just as fine structure is resolvable into tissues and cells.

108. STRUCTURE

Object. — (*a*) *To learn the gross structure and characteristics of a cornstalk.*

(*b*) *To learn something of the fine structure of a cornstalk.*

Apparatus. — Some sections of cornstalk long enough to show the joints or nodes.

(a) **Method.** — Examine the outside and note the rind or skin which covers it, the prominence of the joints, and the groove on one side which shows where a branch was.

Examine the cut-off end and note the compact region near the rind, the loose pith which fills the bulk of the stem, and the woody fibers which are scattered through it. Draw.

Cut a section lengthwise to see how these fibers run and how a section at a joint differs from the other portions.

Conclusion. — State the facts as to covering, joints, amount and location of pith and wood.

Suggestion. — Compare cornstalk with bamboo, rattan, straw, and the stems of grasses. Compare a cross section also with that of a banana stem.

(b) **Method.** — Make very thin sections of stems of young corn plants, using a sharp razor, and mount one in a drop

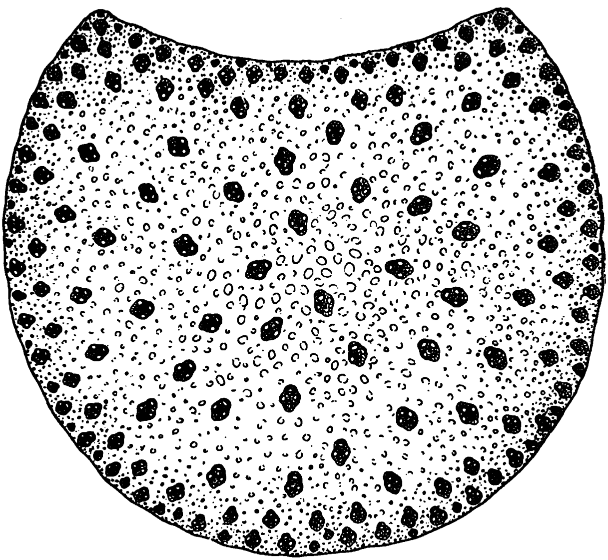


FIG. 42. — Transverse section of stem of monocotyledon (corn), showing the "scattered" vascular bundles.

of water or glycerin on a microscope slide. Cover with a cover glass and examine it with a low power. Move the section slowly to and fro until all parts of the stem have been seen. Notice the compact cells composing the rind, the loose spongy cells which make up the body of the stem, and the bundles which are scattered irregularly throughout the stem.

Where are these bundles largest? Where smallest? Where are they closest together? What advantage is there in this arrangement? Draw one bundle magnified.

Note. — It will be remembered that the corn seed embryo had only one cotyledon. Such a seed is called *monocotyledonous*, a word which means having *one* cotyledon. All plants which spring from monocotyledonous seeds are very much alike in the character of their stems, leaves, and flowers. Such plants are known as *monocotyledons*, or briefly *monocotyls*. Plants which produce seeds of two or more cotyledons are dicotyl plants.

109. STRUCTURE

Object. — (*a*) *To learn the gross structure of a woody (dicotyl) stem.*

(*b*) *To learn the fine structure of a woody stem.*

Apparatus. — Twigs of woody plants one and two years old, also a few sections of stems several years old in which the rings are easily seen. Horse-chestnut, ash, and ailanthus are excellent for the former; and oak, hard pine, ash, and chestnut are good for the latter.

(a) **Method.** — Follow the same general plan as in the preceding Experiment, making out as many answers to the following as possible: By what is the stem covered? What scars and markings are to be seen? What is the cause or meaning of each such scar or mark? Are the joints or nodes conspicuous? Describe the buds and their covering and protection. Where is the pith? How much? Its color and other peculiarities if any? The wood? Its arrangement? How may you tell the age of a stem? Find the rays or lines which extend from the central pith outward toward the bark.

How many layers of bark are distinguishable? How many annual rings? In an old stem find the heartwood and sapwood.

Conclusion. — State the characteristics of the stem studied.

(**b**) **Method.** — As in Experiment 108 (*b*), make very thin sections of dicotyl stems one, two, and three years old. Mount them as before and study them with a low power.

By moving the section slowly across the field of vision, every region will come into view and can be observed in

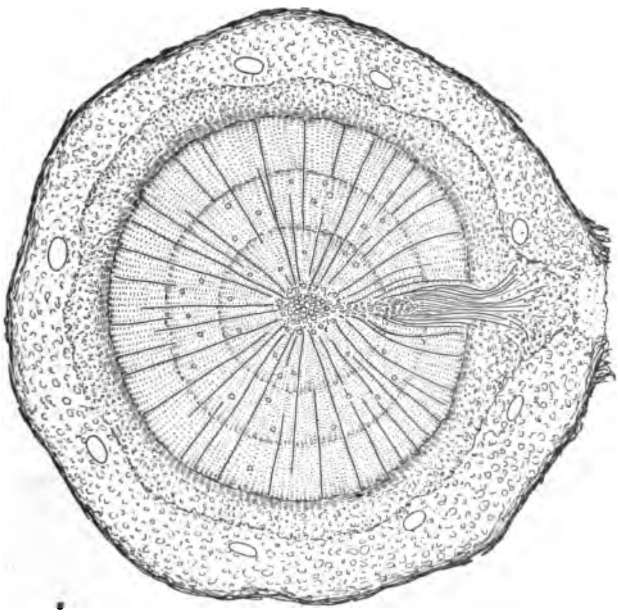


FIG. 43. — Transverse section of a three-year-old twig of *Pinus sylvestris*, showing the small pith, the thick and compact vascular cylinder of secondary wood, and the cortex; radiating lines through the wood represent the narrow pith rays; resin ducts in both wood (small) and cortex (large); to the right is a branch gap in the cylinder.

detail. Compare bark with bast, cambium, and pith, making note of the difference in size and shape of the cells and the thickness of cell walls in the various tissues.

Study the wedge-shaped bundles out of which the first annual ring is formed.

Note how the medullary rays arise from the pinching of the pith between the expanding wedges of wood. Note the difference between that part of the ring which is formed in spring and the part which is a later growth. In which part are the wood ducts larger? What is the probable reason for the difference? Draw a portion greatly magnified.

Read the chapter on woody stems in any textbook of botany and endeavor to find as many structures as possible.

Note. — The study of the minute structure of monocotyl and dicotyl stems is exceedingly difficult. The teacher's assistance is demanded at every point, and the use of texts and charts will greatly aid the beginner.

Prepared microscopic mounts are better than fresh material on account of their greater thinness and the effect of staining reagents.

Exercise

Select good specimens of the two types of stem and compare them part by part.

Cornstalk is the best common monocotyl stem, and some thrifty dicotyl like the ailanthus is very good for comparison. Tabulate your observations as follows: —

	CORN STEM	AILANTHUS
Covering	?	?
Joints	?	?
Pith	Where?	Where?
Pith	Amount?	Amount?
Wood	Arrangement?	Arrangement?
Wood	Amount?	Amount?
New growth	Where?	Where?
Other facts	?	?

Reference Work

What causes the grain in wood?

What is quartered oak?

How is it produced?

Visit a sawmill and see how logs are reduced to various kinds of lumber.

Visit the woods when possible and see how timber is gauged, cut, taken to mill, etc.

Collect as many varieties of lumber as possible and see if you can find rings, rays, pith, bark, etc., in all. Find out from a carpenter what kinds of wood are used for each of the following parts of a house: frame, floors, roofs, clapboards, inside work, shingles; also what kinds of lumber shrink and warp in seasoning.

Find out from observation and inquiry what kind of wood is used for making violins, flutes, piano cases and sounding boards, tubs, pails, baskets, barrel staves, hoops, and heads, athletic goods such as dumb-bells, clubs, and bowling implements.

Why are hoe handles usually of ash and canoe paddles of spruce?

110. TWIGS

Object. — *To find out the parts and markings of a twig and their meaning.*

Apparatus. — Twigs of horse-chestnut at least two years old. Forked twigs are greatly preferred since they show details not always seen on straight ones. A sharp knife is also required.

Method. — Carefully examine the twig and answer the following questions regarding it: —

The Buds. — How are the buds arranged on the twig?

Which buds are largest? Which are smallest? Where are those of intermediate sizes situated? With what are the buds covered? The purpose of this covering? What addi-

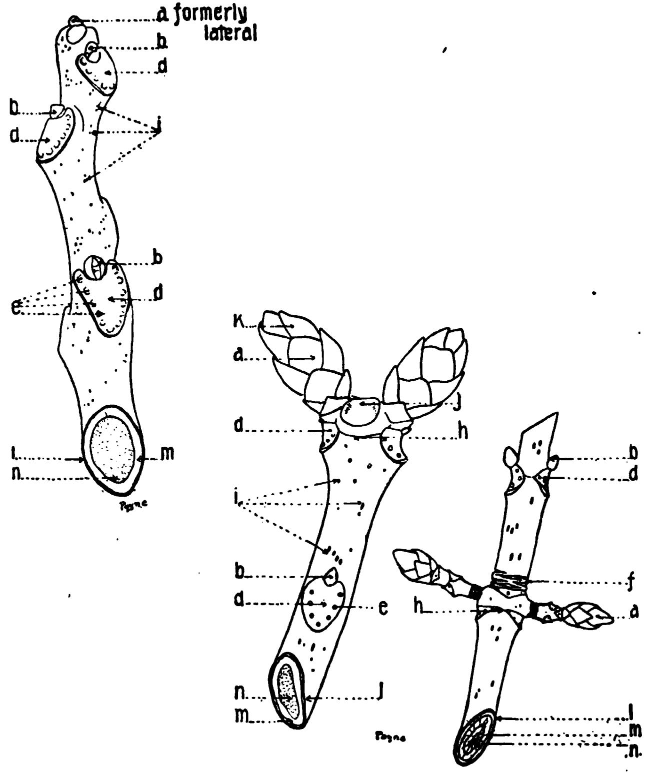


FIG. 44. — Ailanthus and horse-chestnut: *a*, terminal bud; *b*, lateral axillary bud; *d*, leaf scar; *e*, fibrovascular dots; *f*, bud scale scar; *h*, node; *i*, lenticel; *j*, fruit scar; *k*, bud scale; *l*, bark; *m*, wood; *n*, pith.

tional covering do you discover? Its use? Cut open a bud crosswise about the middle. What is found within the bud? What is its purpose?

Remove the bud scales as they come and lay them out before you. How do they differ in size, shape, and texture as they near the center? *Draw.* Cut open another large bud from top to bottom through the center. *Draw.*


FIG. 45. — Horse-chestnut bud expanding.

What is found at the very center? Examine the twig and find scars where the scales of former terminal buds were shed. How does the color of the bark differ on opposite sides of the ring of scars? Why? These rings show the age of the branch. Why?

How old is the branch you have? Cut off the lower end smooth and count the annual rings. Does the number agree with the number of scale scar rings?

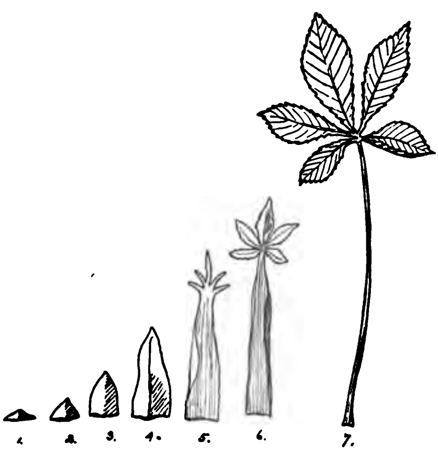


FIG. 46. — Horse-chestnut bud, dissected.

In how many ways may the age of a twig be determined?

Has this twig grown the same amount each year? Can you account for any differences in the amount of growth?

The Bark. — Describe the bark, noting color, smoothness or roughness, etc. Look for the lenticels (breathing pores). Can you discover any system in their arrangement? Is the bark of the same hue on both sides? If darker on one side than on the other, how can you account for it? Is there any way of telling whether the twig grew in a vertical or a horizontal position on the tree? Reasons for your judgment.

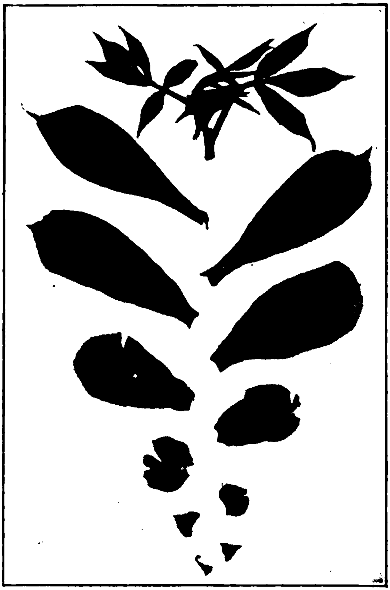


FIG. 47. — Hickory bud, dissected, showing modifications of bud scale.

Remove the outer layer of bark and describe what lies below it. How many distinct layers can be removed?

Scars. — How many kinds of scars can you find on your specimen? What is the shape of the leaf scars (traces) on this twig? Draw a leaf scar enlarged. What scars are found in angles between two forking twigs? Their cause? Do these scars show any dots like those seen in a leaf scar? Why not? Look for node lines (ridges joining opposite leaf scars). Split a twig open through the center and observe the structure at the region of a node.

Count the dots on several leaf scars and determine whether the number is uniform or not. Account for these dots.

Conclusion. — State briefly what has been learned regarding buds, bark, and scars seen on this twig.

Suggestion. — Place several twigs in glasses of water, and after the buds have expanded, make note of the changes that take place. Note how the leaves are packed in the bud (vernation).

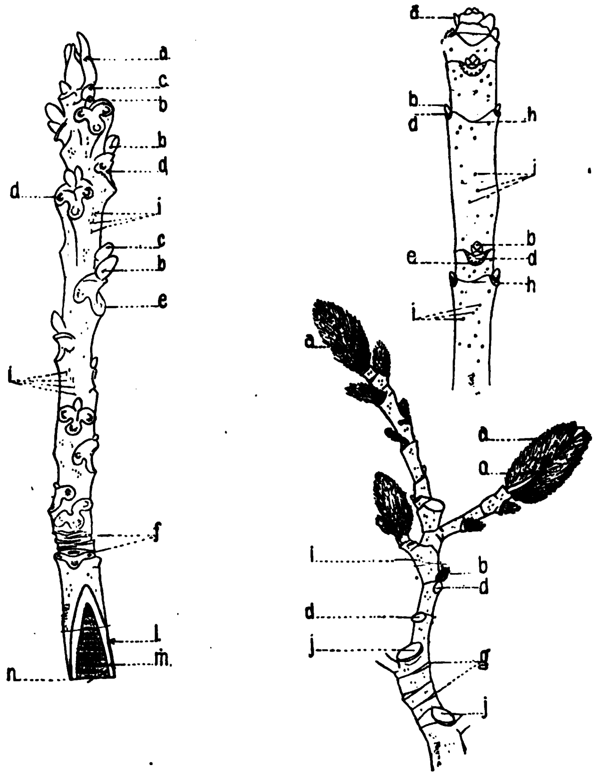


FIG. 48. — Butternut, ash, and magnolia : *a*, terminal bud ; *b*, lateral axillary bud ; *c*, accessory bud ; *d*, leaf scar ; *e*, fibrovascular dots ; *f*, bud scale scars ; *g*, stipule scars ; *h*, node ; *i*, lenticels ; *j*, fruit scar ; *l*, bark ; *m*, wood ; *n*, pith ; *o*, scar of leafstalk.

Make a cross section of a woody stem several years old which grew in a horizontal position. Make a similar section of a vertical branch from the same plant. Compare the thickness of the rings. How do you account for the difference?

111. TWIGS

Object. — *Same as in Experiment 110.*

Apparatus. — Twigs of ailanthus, beech, ash, or apple. Ailanthus is preferable on account of its rapid growth and the great size of all its structures.

Method. — Study this twig in the same way. Its large scars and conspicuous lenticels make it particularly good for study.

Thrust a pin into the topmost bud and fasten a thread to it. Then pass the thread spirally around the twig from bud to bud until it has touched every bud on the stem.

How many buds at a node? Do you find any trace of a node line? Select any bud and look down the stem until another bud is found directly under it. Now count the number of buds passed over by the thread between these two buds. Also count the number of turns made by the thread in traversing the distance.

Select any other pair of buds in the same way and count the number of buds and turns of thread as before.

Is this ratio constant?

Do the same with beech, oak, ash, apple, or any other tree. Compare them with scales on a pine cone.

Look for a scar at the extreme end of the ailanthus twig.

How does it differ from leaf scars, bud scale scars, and fruit scars? What does this terminal scar show? Can you find a terminal bud? Does this plant have definite or indefinite annual growth? Reasons for your answer.

What is the effect of this kind of growth on the form of tree trunks?

Compare the shoots with sumach, bramble, blackberry, and raspberry shoots.

Conclusion. — As in Experiment 110.

Note. — When a plant makes all its annual growth in the spring, it spends the remainder of the season in making preparation for cold weather. This is accomplished by the production of woody tissue in its stem to the very tip and by the development of bud scales for the protection of future branches and flowers. Such a plant is said to have *definite annual growth.*

Many plants, however, keep on growing all summer, and cold weather finds the ends of their stems soft and tender. The first frost kills the tender tips because no wood has had time to mature within them. Thus if warm weather continues into the autumn, such plants will have long shoots. But should an early frost come, these branches will be much shorter. Such a plant is said to have *indefinite annual growth.*

112. TWIGS

Object. — *Same as in Experiments 110 and 111.*

Apparatus. — Twigs of catalpa.

Method. — As in the preceding Experiments. The catalpa represents a different arrangement of leaves and branches. What is it? Are the leaf scars alike in size? If not, which ones are smaller? What does this show regarding the position of the branch on the parent tree?

Conclusion. — Similar to preceding.

Suggestion. — Collect twigs of as many common trees as possible. Mount them on cards for comparison.

Which have opposite branching?

Which have alternate branching?

Which have whorled branching?

Find some having more than one bud at a leaf scar. Find some in which buds occur at unusual places. Find a branch which has been wounded or bruised on which adventitious buds have appeared.

Query. — In what two ways may the age of a given twig be determined? Illustrate, using a twig of apple or horse-chestnut three or four years old.

By what *external* structures may one tell (*a*) when fruit was produced? (*b*) what former seasons were favorable to growth? (*c*) in what position the twig grew on the tree? How may the last two facts be revealed by the *internal* characteristics?

FIG. 49. — Larch.
(Photographed by W. C. Barbour.)

FIG. 50. — Elm.
(Photographed by W. C. Barbour.)

What natural habits of growth make the pine, the spruce, and the fir tree produce unbroken (*excurrent*) trunks? What outside causes may modify these trees, causing them to produce more or less broken trunks?

What natural habits of growth make it impossible for the horse-chestnut, ailanthus, and catalpa to produce excurrent trunks? Such trees are said to have *deliquescent* trunks. Name forest trees which have trunks of this type.

Field Work on Trees

Make excursions into forests, fields, and parks. Study trees growing in the open and compare them with trees of the same sort which are found growing in groves. Make

FIG. 51. — White pine.
(Photographed by W. C. Barbour.)

FIG. 52. — Hickory.
(Photographed by W. C. Barbour.)

notes of differences in height, shape, position of branches, etc.

Make lists of excurrent trees, deliquescent trees, and also those which seem to be of an intermediate form. Find a tree which is normally excurrent, as the pine, spruce, sycamore, but which shows a forked trunk. Try to determine the cause of the difference.

Observe trees to note habits of position of branches. Classify them as erect, arching, ascending, horizontal, drooping, sagging, etc. Learn to identify, trees by their leaves and general appearance, by their bark and by their individual habit of growth. Thus the arching habit of the horse-chestnut, the drooping twigs of weeping willow, the erect shoots of Lombardy poplar, and the curious position of pepperidge make them easily recognized in winter when they are destitute of foliage.

Study the habitat of trees. Which favor moist soil? Which thrive well on rocky hillsides? Which grow along watercourses?

Queries. — How does the bark of beech trees differ from that of oaks, elms, and maples? What bark peculiarities have the birches, sycamores, cherry, sassafras, hornbeam, and cedar? How does the bark on young branches of willow, osier, birch, and poplar compare in color and texture with older branches of the same trees?

How do the shape of the tree and position of branching compare in Lombardy poplar, tulip tree, cypress, spruce, white oak, and pepperidge?

113. SAP CIRCULATION

Object. — *To find out where the sap circulates in stems.*

Apparatus. — Stems of corn and horse-chestnut or any other woody plant freshly cut from the stalk, eosin or any other aniline dye, bottle, and water.

Method. — Repeat the experiment for sap circulation with roots, using the stems instead. Place them in light for half an hour, make sections, and examine them as before. What parts absorb the dye in cornstalk? In the other stem?

From this experiment can you discover any difference between monocotyl and dicotyl stems in location of sap-conducting tissue?

Conclusion. — State in a single sentence where sap rises in each of the stems used.

Suggestion. — Make same experiment, using a potato from which the lower end has been removed. Draw, indicating with colored pencil the region of sap circulation.

114. SAP CIRCULATION

Object. — *To show that sap also circulates downward in stems.*

Apparatus. — Twigs of willow or poplar, knife, and wide-mouth bottle.

Method. — Place the twigs in water, having cut them off smooth to prevent decay. After the adventitious roots have appeared and become at least one inch in length, carefully girdle the twig about two inches above the surface of the water, removing a strip of bark about one inch wide. Keep the apparatus standing for about two weeks and cover it with a bell jar or coat the twig with vaseline to prevent drying out.

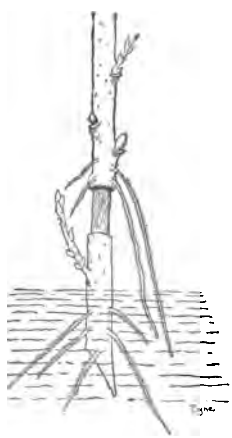


FIG. 53. — Downward circulation of sap.

What happens? Where? Why does this prove that sap in the stem circulates downward? What becomes of the first crop of roots? Why?

Conclusion. — State what evidence is here furnished that sap circulates downward in a stem.

115. SAP CIRCULATION

Object. — *To demonstrate sap circulation in trees.*

Method. — Bind a branch tightly by winding a wire about it several times.

What is the effect on growth *above* the wire?

What is the effect on growth *below* the wire?

Give reasons for the result in each case.

Suggestion. — Procure twigs on which bagworms have hung their cocoons and make an examination of the point about which the web was fastened. How does it compare with the portions on both sides of it? Cut such a twig through the middle and examine the section exposed. What does this show regarding sap circulation in the twig?

Examine a tree about which a wire clothesline has been placed. How has its growth above and below the wire been affected?

What effect follows the use of shade tree branches as anchorages for telephone, telegraph, and electric light poles, etc.?

116. SAP PRESSURE OR ROOT PRESSURE

Object. — *To measure the pressure due to the upward flow of sap in a plant.*

Apparatus. — A vigorous plant of hydrangea having a stem about half an inch in diameter, a T-tube, a bent gauge tube, stoppers, rubber connections, and mercury.

Method. — Cut off the stem of the plant about four inches from the ground and quickly attach the T-tube before the cut surface can become dry. Arrange the apparatus as in Figure 54 and stand it in a favorable location. Water the soil and await results.

What happens to the mercury? Can you account for this? How? What does this show?

Budding and Grafting

In Experiments 86–88 artificial propagation by cuttings and layers was considered. In that method, the propagation of new individuals is due to the ability of a plant to put forth adventitious roots. But it is often desirable to change a plant in order to make it produce a different sort of fruit. This is accomplished by budding or by grafting.

The following principles must be strictly adhered to if this method of propagation is to succeed: —

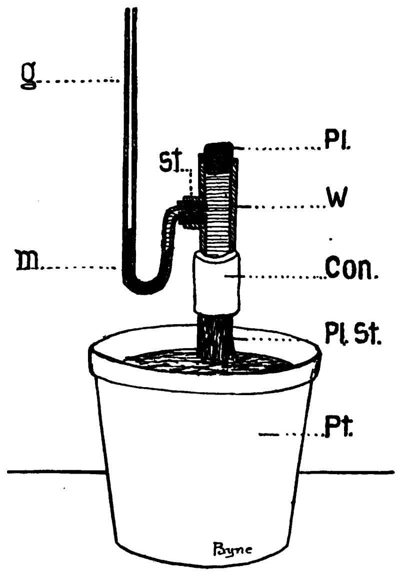


FIG. 54. — Sap pressure: *g*, gauge tube; *st.*, rubber stopper; *m*, mercury; *Pl.*, plug; *w*, T-tube; *con*, rubber connection; *Pl. St.*, plant stem; *Pt.*, flowerpot.

1. *Only closely related dicotyl plants can be engrafted upon one another.* Thus apples of different sorts can be made to grow upon other apples, pears, quinces, crab apples, etc., but they cannot be made to grow on peach, plum, or cherry stocks.

2. *The union between the living tissues (cambium) of both plants must be perfect.* If the living parts do not actually touch, they cannot unite and grow together.

3. *Air must be excluded from the joint until the union has become complete.* If air should get into the joint, there would be a loss of sap through leakage and evaporation; there might be a chance for rain water to get in and dilute the sap; and there would be a liability for the entrance of germs of decay which would prevent a healthy growth.

Definitions. — The plant whose fruit is to be changed is called the *stock*. The buds or twigs which are to be engrafted upon the stock are called the *scions*.

Note. — Budding and grafting are most successfully done in early spring when buds are about ready to start. The scions may be procured in the fall after the leaves have been shed, and the twigs may be kept in damp moss through the winter in a cool place to prevent growing.

117. BUDDING

Exercise. — With a clean sharp knife remove a bud together with a small portion of the attached bark. In severing the bud cut *upward* from beneath the bud to avoid injuring it.

Cut a T-shaped slit in the bark of the tree on which you desire the bud to grow and lift up the two right angles so as to expose the cambium of the stock. Insert the bud so that its cambium touches that of the stock. Push the bud down and smear it around with grafting wax.

Grafting wax can be purchased of any dealer in garden supplies. It is made of rosin, tallow, and beeswax melted together. Cut off the branch of the stock above the bud. This will increase the flow of sap to the bud and insure its early growth.

First attempts are rarely successful, but a little practice will enable one to do it very well.

118. GRAFTING

(a) Slip or Splice Grafting

Exercise. — With a clean sharp knife cut a twig from the tree which is to furnish the scion. Trim it to a slender wedge.

Cut off the end of a branch of the stock, split down the bark on one side so as to expose the cambium; push the scion down until its cut-off end fits firmly against the exposed cambium. Bind firmly; cover with grafting wax.

(b) Cleft Grafting

Another method is used when the scion is a larger branch. Trim the scion to a chisel point and cut a wedge-shaped groove in the end of the stock to fit it exactly. Insert the scion into the stock in such a way that the bark and cambium are in contact. Bind with cord; wax as before.

Note. — There are many methods of cutting the scion and stock, but any way which secures a perfect contact will meet the requirements for growth. See publications of the U. S. Dept. of Agr.

Suggestion. — Examine young fruit trees which are to be planted. Find a swelling near the root. This is where the plant was grafted or budded.

Query. — Why are we told to remove all branches which spring from near the ground on all fruit trees?

In planting fruit trees in a garden or orchard why are we told to set them deep enough to cover the joint where they were grafted? How do you explain the fact that we sometimes find more than one kind of fruit growing on the same tree? How is it possible for two different trees to become united when they grow close together?

119. PRUNING

Object. — *To learn the effect of pruning a plant.*

Apparatus. — Any rapid-growing plant, such as geranium, fuchsia, or coleus, and a sharp knife.

Method. — Remove the terminal bud from a main branch and after a week note the result on the growth of the plant.

In this way the shape of plants can be modified.

How does pruning affect the growth of hedges, ornamental shrubbery, etc.?

Observation. — Go into the woods after a heavy snowfall or violent wind storm. How has nature pruned the trees? Examine the trees which grow in the thickest shade. Look for dead branches caused by overshading.

Examine poplar trees, which are common along city streets, and willows growing in parks and lawns. Look for branches which have died because of overshading by neighboring branches. Trees in which this occurs are said to prune themselves.

This pruning is probably due to the fact that the branches which receive the most light do the most work and so demand the most sap. The overshaded branches, being deprived of their nourishment, gradually die and drop off.

A study of self-pruning will teach us many things which will be of use in artificial pruning.

120. PRUNING

Object. — *To learn the effect of pruning flowers.*

Method. — From a plant which is beginning to bud remove all the flower buds but one and remove also all side branches.

When it blooms compare the flower with others from plants which have not been so treated.

How has the pruning affected the flower?

Observations. — How do florists treat the American Beauty and other popular roses? How do they produce the splendid chrysanthemums and carnations?

Compare the fruit grown on an unpruned apple tree with those which have been produced by a tree carefully pruned.

Which tree produces the greater number of apples? Which one produces the largest and finest apples?

Find answers to the following questions: 1. Why should the branches be cut close to the main stem?

2. Why cut with a *sharp* saw or knife?

3. Why would you not prune an elm or a maple tree as you would an apple tree or a pear tree?

4. How would you prune so as to produce a bushy plant?

5. When is the best time of the year to prune? Why?

6. Find out names of trees that are pruned for each of the following purposes: —

(*a*) To improve the fruit.

(*b*) To alter the shape.

Nature prunes in various ways. Wind storms and lightning rend the trees, causing the weird and grotesque forms sometimes seen on mountains and sea coasts where the trees are exposed to the elements.

Reasons for artificial pruning. — 1. Trees which grow in the open develop a dense mass of twigs and interlacing branches. (Why?) Such trees will produce great quantities of fruit, but it will be small and of poor quality. (Why?) By carefully removing such branches as will interfere with the light of others, larger and better fruit will be produced. (Why?)

2. The struggle after light tends to make trees naturally become tall. By removing those branches which are tallest, the light is admitted to those farther down, and a tree of lower habit is the result. This renders the harvesting of fruit much easier.

3. Since different kinds of trees have different habits of growth, it is necessary for the orchardist to study his trees so as to be able to prune them intelligently. Many valuable fruit trees have been injured through improper pruning.

4. Ornamental shrubbery is pruned to modify the shape. Catalpa, mulberry, privet, box, bay, and osage orange are familiar examples of plants which are pruned in this manner.

When to prune. — The time for pruning depends on the object. Winter pruning is performed when wood production is desired. Summer pruning leads to the production of fruit. August pruning is practiced by orchardists. Hedges are pruned in March before the spring buds have started.

How to prune. — The best implement for pruning large branches is the saw. Smaller branches are removed with pruning shears. After a tree is bearing, the terminal buds can be pruned by merely pinching off in late summer.

In removing branches the cut should be made close to the trunk. A stump should never be left projecting from the main branch, for it furnishes a good place for decay to set in. Suckers from the root should always be kept cut away, since they often come from below the graft and hence they would produce inferior fruit if left to grow. The freshly cut surface of the stump should be painted over to exclude decay germs. In case of splintered branches broken by storms the boughs should be sawed off and painted. All diseased branches should be removed to prevent the spread of infection to other parts of the plant.

Query. — Compare the number of strong, healthy buds on any twig with the number of weak, small, and dormant buds. How many of each?

What are the good results of pruning? What are the bad results of overpruning? Of insufficient pruning? What is the effect of pruning the lower branches? How can pruning cure a crooked tree? Why is the lilac shrub pruned differently from the forsythia? Why do we pinch out the terminal buds of coleus plant used in bedding? How does a plant cover its wounds?

121. GIRDLING

Object. — *To find out the effect of girdling on a woody-stem plant.*

Apparatus. — Any common tree or shrub, and a sharp knife.

Method. — With a sharp knife carefully remove a strip of bark two inches wide clear around the stem about three feet from the end, and cut in deep enough to sever the living part (cambium) which lies just inside the bark. Observe the twig from day to day and make note of the result. How does Experiment 114 explain the result?

Conclusion. — State the effect of girdling on the part beyond the wound.

Note. — In girdling trees the incision is usually made deeper than the cambium, for there is considerable sap in the outer rings (sapwood). The object is to cut off all upward flow of sap from the root.

Reference Work

Directions. — Weigh two potatoes of about equal size and carefully peel the heavier one until they weigh alike. Now leave them lying side by side in a dry place where there is free circulation of air for several days. Reweigh.

Result? Why? Of what use to the potato is the skin?

(*a*) Remove a ring of outer bark one inch wide from a stem. (*b*) From another stem remove a similar ring, but cut deeper, going through the bark to the wood. How do the results in (*a*) differ from those in (*b*)? Why?

Select any common woody-stem plant and with a sharp knife cut from one side a wedge-shaped piece, cutting in almost to the center. After some days examine the wound and see how nature heals it.

122. REPAIRING WOUNDS

Object. — *To learn how a plant repairs injuries.*

Apparatus. — Growing plants, a saw, and a knife.

Method. — Cut off a branch of a plant, and after several days examine the cut-off end and notice how it has healed. Compare woody with herbaceous stems in this respect. Go into an orchard where branches have been removed in previous years. Notice how the tree has healed and is gradually covering up the wound.

If possible, cut a lengthwise section through the stump of a branch which has been pruned and has partly healed over. Where does the new tissue form in healing over an amputated limb?

Conclusion. — State how a tree repairs injuries and where the new growth occurs.

123. TURGOR

Object. — *To show the effect of turgor on rigidity of young plants which have no mechanical tissues.*

Method. — Remove a young bean or pea plant which has been grown in sawdust. Immerse it in water for a few moments until it has become quite stiff.

Now transfer it to a 5 per cent solution of common salt, and let it remain for a short time. Again note rigidity. What has happened? Put it into water again and note the result. Explain. Compare the behavior of these plants with roots treated with strong fertilizers.

124. TURGOR

Object. — *To show the effect of turgor on a dandelion.*

Method. — Split a dandelion flower stalk into two or four parts. What happens? Place it in clear water for five minutes. What occurs? Remove it and immerse in 5 per cent salt solution. What happens? Return it to water and note the result. What causes these changes of curvature?

125. TURGOR

Object. — *To show the effect of turgor on beet root.*

Method. — Immerse some thin slices of beet root in water and after ten minutes examine them. Now place some in 5 per cent salt solution and others in strong syrup of sugar. After one or two hours examine. How do those in the salt solution and those in the sugar solution compare with those which have been left in the water? Repeat this experiment, using slices of cooked beet instead of raw beet. Is there any difference in the results?

Then place those which were in salt and those which were in sugar again in fresh water. Examine again after half an hour. What result? Why?

Query. — How are these experiments related to those on osmosis? How do they tend to explain the recovery of plants after a shower?

126. TURGOR

Object. — *To illustrate turgor.*

Method. — Fill a 30-cc. vial to the brim with a saturated solution of sugar or very thick syrup. Tie over the top a piece of fish air bladder or sheep gut which has been thoroughly soaked in water. Be sure that no air is contained in the bottle.

Fig. 55.

Immerse the whole in a beaker of water and let it stand for forty-eight hours.

Remove it from the water and notice the condition of the membrane. How does it differ from its previous condition? Why?

Now puncture the membrane with a fine needle. What happens when the membrane is punctured? Explain this.

127. TURGOR

Object. — *To show the effect of turgor in an egg.*

Method. — Place an egg in a cup. Cover with vinegar or dilute acetic acid and let it stand until the shell has been dissolved. If vinegar is used, this will require twelve hours.

Immerse the egg in a glass of water for one or two hours. Remove it and examine the egg. Is it hard or soft? How do you account for its condition? Now place the egg in a saturated solution of salt and after two hours again examine it. What difference? Return it to the water. What result?

Food Storage in Stems

Suggestion. — Test various edible stems, such as potato, onion, artichoke, asparagus, etc., for the various nutrients. Which are richest in starch? Sugar? Protein?

Test stems of canna, Indian turnip (Jack-in-the-pulpit), and any other plant having fleshy stems. Do they contain food materials? If so, why are they not cultivated for food by man?

Poisons in Stems

Cut a bit of Indian turnip corm and touch it to the tongue. Describe the taste. Of what use are such substances to the plant?

XII. LEAVES

128. LEAVES

Object. — *To learn the parts of a simple leaf.*

Apparatus. — Leaves of such common plants as elm, maple, geranium, apple, and oak, with portions of the branch on which they grow.

Method. — Be sure to have the leaf entire. Examine it. How many parts does it have? A typical simple leaf has three parts, blade or lamina, leafstalk, and stipules. One or two of these parts may be wanting. How many parts has each of the leaves examined? Examine many plants and determine which have perfect leaves and which have one or more parts lacking. Draw one or more leaves, naming all parts.

FIG. 56. — Parts of a leaf.

Conclusion. — Name the parts of a complete leaf and state where each part is located.

Exercise on the Modification of Simple Leaves

Blade. — Compare leaves of willow, mullein, yarrow, daisy, sunflower, nasturtium, water lily, thistle, dandelion,

maple, grape, etc., as to size, surface, outline, color, shape, and any other differences. Which are broadest in proportion to their width? Which are rough, smooth, glossy, downy, etc.?

Make collections of leaves, press them, mount them on cards, and label them for future reference.

Petiole or Leafstalk. — Compare leaves of poplar, cherry, beech, burdock, tiger lily, tropæolum, sycamore, pitcher plant, water hyacinth, etc., as to length, shape, size, color, appendages, etc. Why are the leafstalks of upper leaves of maple and horse-chestnut shorter than those of the leaves farther down the stem? Compare leafstalks as regards special functions. Of what use is the caplike base of the sycamore (*platanus*), the inflated petiole of the pitcher plant, the swollen spongy petiole of the water hyacinth, the grooved petiole of the burdock and celery, and the tendril-like character of the tropæolum and clematis?

Stipules. — Procure leaves of pansy, locust, sweet pea, smilax, apple, rubber plant, tulip tree, red clover, rose bush, etc. Be careful to secure the entire leaf. Stipules often are so firmly adherent to the stem as to remain attached when the leafstalk is broken away. Some plants also shed the stipules when the leaf unrolls and are supposed to have none when in reality these stipules have already been shed (caducous or evanescent). Notice the modification of stipules. Which help to climb? Which act as a means of defense? Which are leaflike? Which seem to be solely for protection of the bud?

Make sketches showing all forms of stipules seen. Which ones fall off at the opening of the bud? Which ones remain permanently attached to the stem? Study the stem of a rubber plant; sketch the terminal bud with its interesting

protecting scale (stipule). Note the stipular scars which surround the stem at each node. Collect, press, mount, and label a card of stipules.

129. LEAVES

Object. — *To learn something of the framework of leaves.* (*a*) ***Parallel Veining,*** (*b*) ***Net Veining.***

(*a*)

Apparatus. — Leaves of grasses, lilies, calla, canna, banana, etc.

Method. — Examine the leaves chosen and make out the fact that the framework of these leaves is alike in the general parallelism of the veins. Arrange them in two groups, according to the direction of their veins, lengthwise and crosswise. To which group does the onion belong?

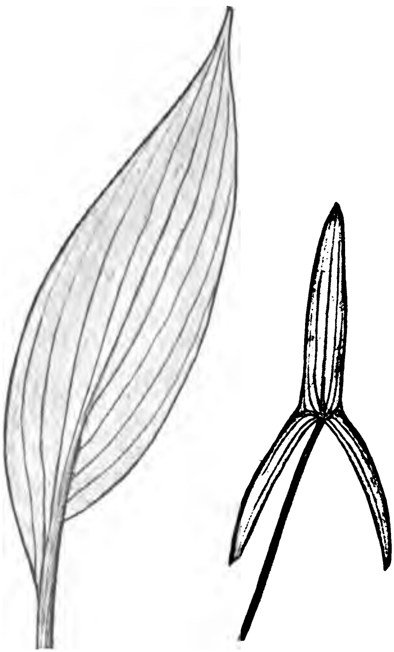


FIG. 57. — Parallel veining.

Tear one of these leaves and observe that the tear follows the direction of the veins.

Conclusion. — How many types of parallel veining are there? How do they differ?

(*b*)

Apparatus. — Leaves of apple, oak, or poplar. Any firm-veined woody plant will do.

Method. — Examine the leaves selected, giving special attention to the under surface where the veins are more prominent. The network is easily discovered in most leaves, but in cases of some leaves it will be necessary to hold them between the eye and the light. Fleshy leaves often do not show their net veining because there is so much pulp in them. Tear a leaf as in the preceding Experiment and note how irregularly it tears. Why? Study the general plan of the veins and discover if possible the general scheme of veining.

Fig. 58. — Net veining.

Conclusion. — How many types of net-veined leaves can you find?

Note. — The veining of leaves usually indicates the kind of plant, whether monocotyl or dicotyl.

Parallel veining is never found in dicotyl plants, and net veining very rarely in monocotyl plants.

Such monocotyls as arrowhead (*sagittaria*), elephant's-ear (*caladium*), and a few others seem to have net venation, but a close examination will show that the veins run generally parallel with each other and only the large ribs form a sort of network.

Leaf Impressions

For greater ease in studying leaves, the use of leaf impressions is very helpful. They may be made in the following manner: —

Apply a preparation of vaseline and lampblack to the under surface of the leaf, using a dabber made of tightly rolled cotton batting covered with chamois skin.

The leaf should be touched lightly all over its under surface, and great care should be used *not* to have much of the preparation on the dabber.

The leaf, coated with the preparation, is laid upon the paper upon which the impression is to be made and placed between two folds of cardboard. Run this through a clothes wringer, and the impression will be complete.

A little practice will enable one to produce beautiful impressions which surpass half-tones in delicacy and accuracy.

Note. — *How to make the impression ink.* Mix thoroughly together a tablespoonful of vaseline with a teaspoonful of lamp-black. Melt the mixture and stir it until it is uniformly black.

How to use it. Place a small portion of the preparation on the middle of a plate of glass. What can be taken on the point of a knife blade is plenty.

Spread this ink evenly over the glass by dabbing it with the dabber mentioned in the preceding exercise, and use the plate as long as any ink remains upon its surface.

In this way there will be no unevenness in the blackness of the impressions.

If carefully made, the finest details of veining, outline, and surface features will be distinctly shown.

Skeleton Leaves

The framework of many leaves may be studied from their skeletons. Skeleton leaves are very beautiful, are easily made, and are useful for study. As permanent mounts under glass they are an attractive addition to the school museum.

Skeleton leaves are made as follows: —

(*a*) Select leaves having a more or less firm framework, such as oak, elm, apple, holly, and beech. The Judas tree (*cercis*) is the easiest leaf to skeletonize.

(*b*) Place the leaves in a saucepan with enough water to cover them and add a heaping tablespoonful of cleaning powder. Set it over the fire and let the solution boil for fifteen minutes. This cooks the pulp.

(*c*) Remove the saucepan from the fire, place the leaves in a basin of clear water, and allow them to remain for a few minutes. This removes the alkali.

(*d*) Place one leaf on a dinner plate and let water drip on it. The leaf will spread out upon the white surface of the plate, and the water will remove the pulp, leaving the network clean.

FIG. 59. — Skeletonized leaf of Jûdas tree.

(*e*) A little bleaching powder can be used if it is desired to bleach the specimens, and solutions of logwood or aniline dyes can be employed if one wishes to stain them. But the natural color of the veins is best.

(*f*) After the pulp has been removed, the skeleton can be transferred to blotting paper and laid in a book until thoroughly dry.

(*g*) Mounted under glass, they will keep indefinitely for class use; and if placed between two glasses, they make handsome transparencies. They may also be used in lantern slides, where they are very effective.

Suggestion. — Mount a bit of skeleton leaf on a microscope slide in a drop of water. Cover it with a cover glass and examine it with a low power. If the skeleton leaf has been carefully prepared, the terminations of veinlets will be seen. *Draw.* Permanent mounts may be made by

immersing the specimens in absolute alcohol for a short time to remove any water which may be in them. Then transfer them to xylol, after which they may be mounted in a drop of Canada balsam.

Whole leaves skeletonized may be placed between plates of glass, and passe partout tape or gummed paper may be used to bind the plates together.

The Use of Blue Prints in Leaf Study

Lay leaves of all forms upon sheets of blue print paper, arranging them with reference to different forms or other characteristics.

Fig. 60. — Specimen of blue print work.

This should be done in a shady or semidark room. Cover them with a glass plate and then expose them to direct sunlight for two to five minutes. Then remove them to a shady place and wash them thoroughly in pure water for five minutes.

These blue prints can be dried between blotters and mounted while still damp or kept unmounted for reference.

Series of blue prints illustrating forms of apex, base, margin, shape, and any other conspicuous features may be so prepared, also many flowers, flower clusters, and such delicate objects as thistledown, milkweed seeds, and feathers.

Formula for Blue Print Paper

Solution I.	Potassium ferricyanide . .	1 oz.
	Water (distilled)	5 oz.
	Gum Arabic	1 drachm
Solution II.	Iron-ammonia citrate (green)	1½ oz.
	Water (distilled)	5 oz.
	Gum Arabic	1 drachm

Directions for using — Mix equal parts. Coat paper *in the dark* by use of oil lamp or yellow light. Dry the paper quickly by heating and keep it in a dry, dark place. Select by preference a paper which has a good sizing, such as foolscap. The mixed solution should have a wine color, and the dry paper a lemon yellow. Print until the dark parts are bronzed and wash the paper thoroughly in cold water. Prints can be brightened by adding a trace of citric acid to the last water.

Note. — No rule can be given for the time required for exposure, since blue print papers vary in sensitiveness to light and the objects used are so different in thickness. Thus the so-called "*French-satin-junior*" paper is very sensitive, while many of the common papers used by architects require a great deal longer time for exposure. Objects like feathers, thistledown, and semitransparent leaves may require but a minute, while old leaves may be exposed for an indefinite time.

A little practice will show the experimenter how to get the best results.

130. LEAVES

Object. — *To find out the relation of form to the framework of leaves.*

Apparatus. — Leaves of (*a*) beech or elm, and (*b*) maple or ivy.

Method. — These leaves represent the two types of net-veined leaves, known as *feather-veined* and *palmate-veined.*

Lay the leaves down and compare their system of veining and the general outline. How many principal veins has the ivy or the maple? How many points to the outline? Does the number of principal veins correspond in any way to the number of lobes of the blade? In the beech and elm does the shape have any

FIG. 61. — Feather-veined leaf.

FIG. 62. — Palmate-veined leaf.

relation to the framework? Trace one of the main veins to its termination. What do you find there? Is there any relation between the feather veining and the outline?

Conclusion. — State the relation of form to framework of leaves.

131. LEAVES

Object. — *To find out where the sap flows in a leaf.*

Apparatus. — Stems bearing leaves or leaves with long leafstalks, a bottle, and eosin solution.

Method. — Treat the leaves in the same manner as the root was treated in Experiments 75 and 113. Where does the leaf become stained? Cut off sections of the leafstalk and see if you can tell where sap flows in that part. If this experiment is made with large, coarse leaves like rhubarb, burdock, celery, or cabbage, some very pretty results will follow.

Conclusion. — State what part of the leaf furnishes a channel for sap circulation.

132. LEAVES

Object. — *To show that leaves exert an upward pull on sap flow.*

Apparatus. — A vigorous young shoot of ailanthus or other equally strong plant, rubber tube, glass tube, beaker, retort clamp, and mercury.

Method. — Cut off the branch *under water* to prevent entrance of air at the cut surface.

Fit the piece of rubber tubing tightly about the stem and insert the other end in the glass tube, fitting it air-tight. Wax the joint as an additional precaution and fill the glass

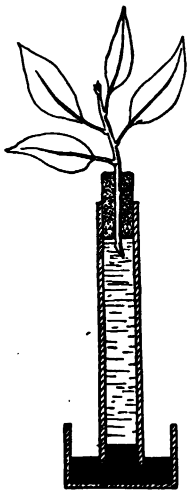


FIG. 63.

tube with water which has been distilled or boiled to expel any air. Stand the tube over the beaker of mercury as shown in Figure 63.

After a few hours note what has occurred. How do you account for the result?

Conclusion. — Your inference from this.

Note. — The effect of light on the root was shown in Experiment 94 and its influence on stems was seen in Experiments 103 and 104. We will now make similar experiments and see how light acts on leaves.

133. LEAVES

Object. — *To discover the effect of light upon foliage.*

Apparatus. — The dark box used in Experiment 51, also another similar box having a small hole or window with an interior cut-off so arranged as to prevent the direct rays from reaching the plant within. Plant some young vigorous seedlings in small pots.

Method. — Place a plant in each dark box and also one outside where it will receive plenty of light. Let them remain for several days and then compare them.

Observe the following: —

(1) Color of each plant.

(2) Vigor or weakness of its growth as compared with the others.

(3) Position of the plant in the box.

(4) Size of the leaves.

(5) Length of the internodes.

Conclusion. — What may be inferred regarding the effect of light on foliage?

134. LEAVES

Object. — *Same as in Experiment 133.*

Apparatus. — A vigorous potted plant, cork disks made by making thin sections of an ordinary bottle cork, and pins.

Method. — Place the cork disks upon leaves so as to cover opposite faces and hold them in place with a pin (Fig. 64). Leave the disks in place for three or four days, then remove them and note the result (Fig. 65).

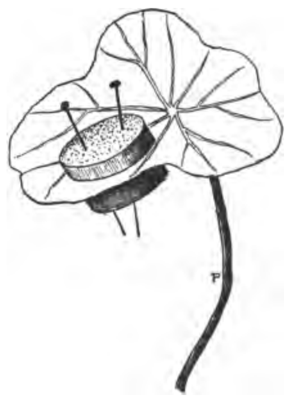


FIG. 64.

Conclusion. — What is the effect of shutting off light from any part of a leaf?

Query. — Why do gardeners bank up their celery? What is the effect? What other crops are bleached in this way?

Fold a piece of black felt or thick black paper and punch or cut a hole through both folds. Then lay a leaf between the folds and pin it so that it will remain in position. The leaf will thus be covered with only that portion exposed which is under the hole.

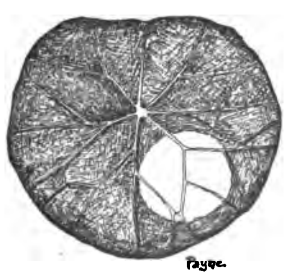


FIG. 65.

Set the plant where it will be exposed to strong sunlight and leave it for three or four days. When the covering is removed the leaf will show a green spot where the surface was exposed. All the remainder of the leaf will be pale or almost white (Fig. 66).

Suggestions. — Select a plant of

erect habit and notice the position of the leaves with reference to the stem on which they grow.

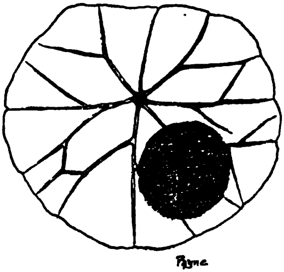


FIG. 66.

Now bend a branch over and weight it so that it will occupy as nearly as possible a horizontal position.

After a few days remove the weight and bring the branch back into its original position. What is the position of the leaves now? How do you account for this change? Observe the same branch again after another week. What is the position of the leaves now? (See Ex. 149.)

Compare erect with drooping branches on deutzia, snowball, and other garden shrubs.

135. LEAVES

Object. — *To study the direction of growth.*

Select a young vigorous sunflower plant growing in a flowerpot. A plant having four or five leaves is a convenient one for the purpose.

Lay the flowerpot on its side between two blocks. (1) Make a sketch of the plant. (2) After an hour or two observe the plant. Note any change of position in leaf or stem and sketch it again. (3) Continue making observations and sketches until the stem has assumed a vertical position.

Which responded to the change of position, leaf or stem? Which part of the stem was first to change its position? What leaves were first affected? Which last? Which, if any, not at all?

Select a vigorous potted plant of sunflower or tropæolum and lay the flowerpot on its side. On a sheet of paper make a diagram of the flowerpot and one or two fresh young leaves. Let the flowerpot remain so for a day, then make a sketch in dotted lines on the diagram, showing the new position of the leaves.

Suggestion. — Observe a geranium which has been growing in a window box for some time. How do the plants on the sunny side compare with those on the shady side as to the position and number of their leaves?

Note. — Good examples of both negative heliotropism and negative geotropism are seen in such vines as climb by adventitious aërial roots. In the trumpet creeper (*tecoma*) the climbing roots project away from the sun and away from the soil. Prove this by the following experiment: —

Choose a stem on which the roots are beginning to attach themselves. Turn the stem half round so as to get the roots into the light. Fasten the vine to prevent its return to the former position.

After one week, observe it. Have the roots responded to the change of position?

136. LEAVES

Object. — *To show that plants give off water.*

Apparatus. — As shown in Figures 67 and 68.

Method. — Cover a plant as in Figure 67, using rubber tissue or waxed paper to cover the soil and a wide-mouth bottle inverted over the plant. Or use a tumbler over a leaf as shown in Figure 68, letting the petiole project through a hole in the card which covers the battery jar, and plug the hole around the stem with cotton batting.

When the plant has been arranged according to one of these ways, stand it in a shady place or one where the sun-

shine does not fall strongly, and await results. After half an hour what do you find forming on the inside of the glass or tube? How do you account for this?

FIG. 67.

FIG. 68.

Conclusion. — State what this experiment proves.

Query. — If leaves are constantly giving off water, how does it affect the air? How do you account for its wilting when a leaf is removed from its stem? Why does the United States government encourage tree planting in the Western states?

137. LEAVES

Object. — *To show that leaves give off water.*

Apparatus. — Two tumblers, blotting paper, two leaves, and two plates.

Method. — Line one tumbler with blotting paper and dampen it, but do not have it wet enough to drip. Wipe the other dry. Place a leaf in each tumbler and cover them with the plates. After one hour remove both leaves. How

do they differ in appearance? Give the probable reason. Do you find any moisture in the glass which was dry at the start?

Suggestion. — Place a spray of hydrangea in a bottle of water. Set it in one scale pan and balance it. What happens after an hour or two? Why? How do you account for it?

Repeat the experiment, using a potted plant in a scale pan, having first sealed the pot with paraffin paper. Then counterpoise it.

Procure three test tubes or slender bottles of the same size and shape. Fill them three fourths full of water and mark the level with a thread or rubber band. Label the tubes *a*, *b*, and *c*. Now select from the same plant or from plants of the same kind two branches of equal size and bearing the same number of leaves.

Place them in two of the tubes thus: —

(*a*) Tube open, containing nothing but water.

(*b*) Tube open, but containing a branch from which the leaves have been removed.

(*c*) Tube open, containing the other branch bearing all its leaves.

After six hours note the level of the water in each tube. Which tube loses most water? How do you account for the difference?

138. LEAVES

Object. — *To find out the relative amount of mineral matter in leaves.*

Apparatus. — Young leaves from new shoots and old leaves fallen from the same tree, evaporating dishes, and Bunsen burner.

Method. — Dry the leaves thoroughly and burn them. Which leaves contain the greater amount of ash? Account for this.

Conclusion. — State whether young or old leaves contain more mineral substance.

Note. — Compare the crust of lime left in a teakettle with the mineral left in a leaf. What corresponds to the steam that comes from the kettle? Trace a drop of water from the soil through a plant until it returns to the atmosphere.

How do you account for the presence of potash in wood ashes?

139. LEAVES

Object. — *To find the cause of wilting and recovery.*

Apparatus. — Leaves of hydrangea or other similar plant, tumbler, and water.

Method. — Cut off a leaf and let it lie upon the table in the sunlight until it is wilted. Then place the leafstalk in water. What happens? Repeat the experiment, putting only the blade in water. Does it recover?

Conclusion. — What causes a leaf to wilt? What causes it to recover? How does water get into the leaf? Where does it go out?

140. LEAVES

Object. — *To find out which surface of a leaf gives off most water.*

Apparatus. — Four leaves of hydrangea or other plant of similar kind which wilts easily, vaseline, or olive oil.

Method. — Suspend the four leaves by threads so that all surfaces will be equally exposed to the air.

No. 1. Leaves in natural state.

No. 2. Coat *upper* surface with vaseline.

No. 3. Coat *lower* surface with vaseline.

No. 4. Coat both surfaces with vaseline.

Also vaseline the leafstalk of each leaf. After a few hours make observations on all the leaves. Result?

Conclusion. — Which surface gives off most water?

FIG. 69.

141. LEAVES

Object. — *Same as in Experiment 140.*

Apparatus. — Two watch glasses, any plant with large succulent leaves, and a rubber band or other means of fastening the glasses in place.

Method. — Place the watch glasses on opposite sides of the leaf and allow them to remain there in a shady place for some time.

In which glass does most of the dew collect?

Conclusion. — Same as in Experiment 140.

142. LEAVES

Object. — *Same as in Experiment 140.*

Apparatus. — Cobalt paper,[1] leaves, and plates of glass.

Method. — Dry the cobalt paper over the flame of a lamp. Lay a dry leaf between two pieces of the dried cobalt paper. Place the whole between plates of glass which have been wiped perfectly dry.

[1] Cobalt paper is prepared by wetting filter paper with a solution of cobalt chloride. Dry it thoroughly over a gas flame until it becomes blue. Dampness in air will cause the blue to disappear and the paper will become red.

After ten or fifteen minutes note the result.

What occurs? Which paper changes color more quickly? What may be inferred from this?

Note. — Cobalt paper may also be used in the following manner: If two bell jars are wiped dry and into each a piece of dried cobalt paper is put, both will retain their blue color indefinitely because the air remains dry.

But if a plant or branch from a vigorous plant is placed in either jar, the cobalt paper will soon begin to turn red, showing the presence of moisture in the air. This moisture can of course come only from the plant, since the other paper retains its blue color. Other modifications of this experiment will readily suggest themselves.

Query. — Do thin leaves give off water more quickly or less quickly than thick ones? Does a cactus yield moisture as easily as spinach or lettuce? Compare rhododendron leaves with rhubarb, and houseleek with geranium.

143. LEAVES

Object. — *To find how much water is given off by a plant in a given time.*

Apparatus. — A small, healthy potted plant having large leaves, rubber cloth, and scales.

Method. — Weigh the plant after having watered it and covered the flowerpot and soil up to the stem with the rubber. The only exposed surface will thus be the stem and other parts above ground.

After three or four hours weigh the flowerpot again and note the loss. If the plant has been carefully covered, the loss must be due to water transpired through the leaves.

Conclusion. — Answers will vary with kind of plant, number of leaves, and conditions of moisture in the atmosphere.

144. LEAVES

Object. — *To measure the amount of transpiration.*

Method. — Magin's apparatus to measure the amount of transpiration is shown in Figure 70. Push into one arm of a U-tube a rubber stopper through which a leaf or branch has been passed. Fill the tube with water and into the other arm push a stopper through which passes a long piece of glass tube bent at right angles near the stopper. The water should not only fill the U-tube but extend out into the tube. As the plant transpires, the water contained in the tube will gradually move along the tube towards the U-tube. The rate at which it moves along will indicate the rate of transpiration.

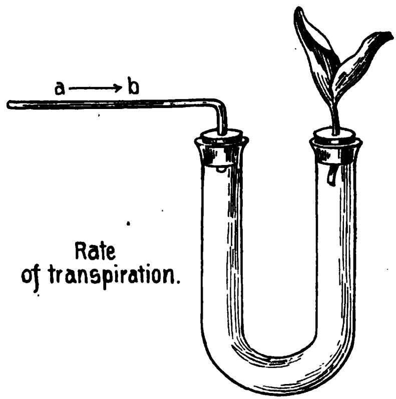


FIG. 70.

Suggestion. — Lay two large leaves like those of the hydrangea on a table in sunshine until they have begun to wilt. Then place one with blade under water and leafstalk out in the air. Place the leafstalk of the other in water with the blade in air. After an hour or two what change has taken place? Do both act alike? Account for the difference if they are not alike.

What may be inferred from this experiment?

Do leaves absorb water from their surfaces?

How are leaves of cabbage, mullein, caladium, and water lily adapted to prevent wetting?

145. LEAVES

Object. — *To show that leaves give off oxygen.*

Apparatus. — Battery jar, funnel, test tube, and some water plants, such as nitella or other submerged pond plants.

Method. — Place the plants in water in the battery jar, invert the funnel over them, and fill the test tube with water and invert it as in Figure 71.

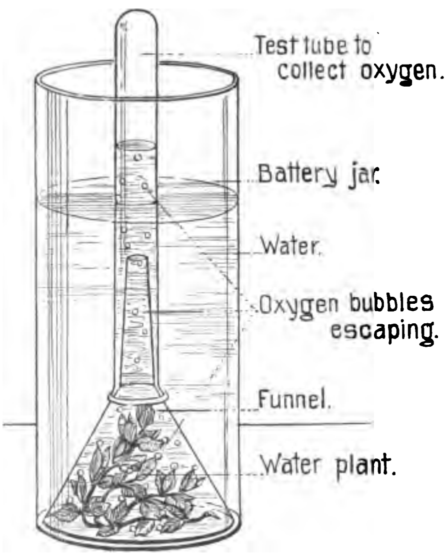


FIG. 71.

Set the whole apparatus in the strong sunlight. What happens? Remove it to a shady place. Result? Again set the jar in sunlight and allow to remain until the test tube is filled with the gas.

Remove the test tube and test for oxygen with a glowing splinter as in Experiment 1.

Conclusion. — State the result of your test.

Note. — If the water about the plants is charged with a little carbon dioxide before this experiment is made, there will be much more oxygen produced than if ordinary water is used.

Generate the carbon dioxide with marble and sulphuric acid; otherwise proceed as in Experiment 3 and pass a little of the gas through the water.

Sulphuric acid is preferable for two reasons: first, because it sets the gas free less rapidly than does the hydrochloric acid; and second, there are not so likely to be any acid fumes which might injure the plants.

To Teachers.—It is sometimes preferable to charge the water *before* the class-room experiment.

If the class is advanced, the charging had better be done during the class-room experiment, but with young students the more simple and direct the experiment, the better.

Suggestion. — Procure a branch of some water plant such as potamogeton or other aquatic plant having stems of good size.

Tie the branch to a glass rod and place it in a tall beaker or battery jar of water so that it will be entirely submerged.

Now place the jar on the window ledge where it will receive plenty of strong sunlight.

Observe the plant. Do any bubbles collect on the leaves? If so, what are they? Look at the cut-off end of the stem. What occurs there? What is it? Give reasons for your answer. Of what advantage are hollow stems to water plants? Do the hollow stems of land plants like bamboo, rush, etc., serve the same purpose? Reasons for your answer.

146. STOMATA (optional)

Object. — *To demonstrate the presence of stomata.*

Method. — With a sharp knife peel off a strip of skin from the under surface of any leaf and mount it in a drop of water or glycerin under a cover glass. Examine it first with a low power to see the cells of which the skin is made and note the large number of kidney-shaped cells in pairs placed with their concave sides together. These are the *guard cells.* Between the guard cells will be seen a narrow slit, the *stoma,* through

which air is taken into the leaf and air and moisture are given out.

Compare the upper and under surfaces of the same leaf. How do they compare in number of stomata? Do your observations in this respect agree with the results of experiments on transpiration?

Note. — The epidermis of iris, lily, onion, houseleek, and fern are easily removed.

147. CELLS (optional)

Object. — *To demonstrate the cellular structure of leaves.*

Method. — Mount bits of skin of leaves or thin slices of pith in water or glycerin and study the individual cells.

Make out the following points of cell structure: —

(*a*) The *cell wall*.

(*b*) The cell contents (*protoplasm*).

(*c*) The *chloroplasts*, or grains of yellowish green material which are found in some of the cells.

(*d*) The *nucleus*, a sort of kernel or denser mass usually near the center of a living cell.

If the nucleus is not clearly seen, place the section in methyl green for a few minutes, and it will usually become stained.

Make drawings of as many different forms of cell as you are able to find.

Onion and lily epidermis have cells which are very unlike those of fern. Pith cells are very unlike guard cells in shape.

Root hairs are epidermal cells of the root which are prolonged outward, increasing the absorbing surface of the root (Ex. 91). Cells of endosperms (Ex. 40) contain starch.

In Experiments 214–220 cells of yeast are considered.

Note. — For general consideration of the cell and protoplasm see also Experiments 226–228.

148. LEAVES

Object. — *To show that leaves purify the air.*

Apparatus. — A healthy, freshly cut shoot of any vigorous green plant, two tumblers and a shallow basin of water, vaseline, a piece of glass or rubber tube ten or twelve inches long, and two pieces of plate glass three inches square.

Method. — Fill both tumblers with water to exclude the air. Into one of them place the shoot, top down. Now invert both glasses under water so that they stand as in Figure 72. By means of the tube blow into each tumbler until they are completely filled with impure air from the lungs.

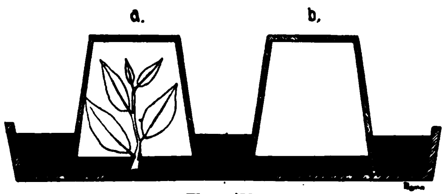


FIG. 72.

Set the tray containing the inverted tumblers in a sunny window and leave it there for two or three days.

After two or three days grease the two glass plates liberally with vaseline. Then *very carefully* slip them under the tumblers so that they shut them air-tight.

Now with a burning stick test the contents of each tumbler. Is there any difference in the way the stick burns in these two glasses? Both originally contained impure air from the lungs. What is the difference between the contents of these tumblers now? Can you account for this?

Conclusion. — State what effect plants have on the air.

Query. — Give reasons why the planting of shade trees

is an advantage. Why are parks desirable in crowded cities? Why is the air in the country purer than city air? Is it a good thing to cultivate plants in the house? Did this experiment require light? If so, is there any reason why we should not have large numbers of house plants in a sleeping room?

Suggestion. — Repeat this experiment, using gas formed by burning a taper under the glass instead of using air from the lungs.

With advanced students this experiment may be varied by filling the glass with different gases. Will a plant remove hydrogen? Oxygen? Pure carbon dioxide generated by action of acids on marble?

149. LEAVES

Object — *To show that leaves make starch.*

Apparatus. — Green leaves, alcohol, lamp, and iodine solution.

Method. — Place any green plant in the strong sunlight for a day. Then snip off a leaf and plunge it into boiling water for one minute. Remove it from the hot water and immerse it in alcohol. What is the effect of the heating and alcohol upon the appearance of the leaf ?

Now add a drop of iodine solution to the bleached leaf and after a minute remove it and rinse it in water.

Examine the leaf to detect blue color due to the presence of starch.

Or, scald in water leaves treated in Experiment 134 and treat them as above with alcohol and iodine solution. The exposed spot will take on the characteristic blue of the starch test, while the remainder of the leaf will show no trace of starch.

Conclusion. — State the result of these experiments as to

the relation of light to green coloring matter (chlorophyll) in plants, also the relation of these to starch making.

Suggestion. — Repeat this experiment, using a leaf picked from the plant early in the morning before the sun has shone upon it. Does the leaf give the same starch tests? How do you account for the difference?

Note. — The color of green plants is due to the presence of small green grains called *chloroplasts*. They may be seen with a low power of the microscope if thin sections of leaves be examined in a drop of water or glycerin. These small bodies have the power of making starch out of water and carbon dioxide in the presence of sunlight. In this process, called *photosynthesis*, oxygen is set free.

The leaf is a sort of factory in which water and carbon dioxide are the *raw materials*, the chloroplasts are the *machinery*, sunlight is the *energy*, starch and other substances are the *finished product*, and oxygen is the *waste product*.

Only *green* plants are capable of making starch.

150. LEAVES

Object. — *To prove that it is only in the green part that starch is made.*

Apparatus. — Spotted leaves of such plants as silver-leaf geranium and some varieties of coleus, also any dicotyl albino plants, and the same tests as used in the preceding Experiment.

Method. — Treat the leaves as in the foregoing Experiment by boiling the leaves for a few minutes in water, then soaking them in alcohol and adding iodine solution. Which part of the leaf turns blue? Inference?

Conclusion. — State what kind of plants and what parts of plants are engaged in starch making.

Suggestion. — Test mushrooms and other fungi, also red or yellow plants like dodder, in the same way.

Also test monocotyl plants like ribbon grass, tradescantia, etc., which have their leaves streaked with white. Do the monocotyls give equally good tests for starch? How do you account for the difference? Test the same plants for sugar. Result?

Query. — What has been shown in previous exercises as to the necessity of light for growth of plants? How does light affect the direction of growth of stems? The position and arrangement of leaves? The vigor of plants? The color and size of leaves? What substance do leaves *absorb* from the air? Does this take place equally in the *light* and *darkness?* What substances are *given off* by leaves? Give proofs for each substance mentioned. What substances are manufactured by leaves? Can these substances be made in darkness? What part of the leaf makes the starch? By what energy? Out of what substances? What waste product is set free at the same time?

151. LEAVES

Object. — *To observe the effect of closing up the stomata of a leaf.*

Apparatus. — Any healthy plant, preferably one of the common deciduous plants, and vaseline.

Method. — Without removal from the stem coat both surfaces of a leaf with vaseline, being sure to cover all stomata. After three or four days apply tests for starch and sugar. What result?

Conclusion. — State whether air is needed by a leaf to make starch.

Query. — How may this be explained? What happens to a leaf which has been coated with vaseline if allowed to remain attached to the stem?

152. LEAVES

Object. — *To show that leaves give off carbon dioxide.*

Apparatus. — Two wide-mouth jars, two vials of limewater, and leaves.

Method. — Put about one inch depth of water in each jar. Into *one* jar put a number of vigorous leaves so that the leafstalks are in water and their blades in the air of the jar. Leave the other jar as a control. Place a vial of limewater in each jar so that it does not mix with the water of the jar. Cover both jars and set them away in a dark closet for a day or two. Examine the limewater in each jar. Which gives the better test for carbon dioxide? Explain.

Conclusion. — What does this show concerning respiration of plants?

Note. — There is a trace of carbon dioxide in the air. Hence there will usually be a thin scale of carbonate on the surface of the limewater in each vial.

153. LEAVES

Object. — *To show that young buds respire and give off heat.*

Apparatus. — Same as in the preceding Experiment, a thermometer, and several expanding leaf buds of horse-chestnut, hickory, ailanthus, or maple.

Method. — Same as preceding. Test the temperature with a thermometer from time to time and compare it with the temperature of the air outside.

Make similar observations with the apparatus in the light. Are the results alike in both cases?

Conclusion. — What may be inferred from this experiment?

154. LEAVES

Object. — *To study the fall of a leaf.*

Apparatus. — Any healthy deciduous plant such as maple, ash, ailanthus, hickory, or horse-chestnut, a large black cloth or a dark box.

Method. — Cover the leaves of one branch or cover one leaf with the cloth, having first dampened it, or place the leaf in a dark box and stop up the aperture so as to shut out light. Let the apparatus remain for at least a week, then remove the coverings and note the result.

Note. — The leaf will usually drop off and its leaf scar on the stem will be found as in autumn.

Conclusion. — How may this be explained ?

Query. — Why do leaves on a tree, where they are overshaded, turn yellow and fall during the summer?

Food Storage in Leaves

It has been shown that green leaves manufacture foods. In some plants the various food products are transferred to other parts of the plant and stored there. The fleshy roots and stems have been shown to be storage places for food.

In some plants the leaf is also used to store food.

In the foregoing experiments we have found starch in the leaves after exposure to sunlight.

Suggestion. — Test leaves of lettuce, spinach, cabbage, celery, etc., for starch by first soaking in alcohol to remove the chlorophyll and then look for blue color after treating with iodine solution. For sugar macerate the leaves in water, filter, and test for sugar.

For oils and fats dry the leaves and treat them with alcanna solution or with Soudan III.

Leaf Modifications showing Adaptation of Form to Function

Modification	Function	Examples
Foliage	starch making, respiration, transpiration, etc.	most plants
Spines	defense	cactus, barberry
Tendrils	climbing	pea, gourd
Thickened	food storage	houseleek
Thickened	water storage	agaves
Bulb scales	food storage	onion, tulip
Bud scales	protection of young branch or flowers	deciduous plants
Floral parts	reproduction	flowering plants
(*a*) sepals	protection	
(*b*) petals	protection and attraction of insects, birds, etc.	
(*c*) stamens	male reproductive	
(*d*) pistils	female reproductive	
Bracts	various	
	(*a*) as floral parts	dogwood euphorbia
	(*b*) as spathe	calla, Indian turnip
	(*c*) seed dispersal	basswood
Dissected	various	
	(*a*) a light relation	yarrow, ferns
	(*b*) a water relation	water buttercup water milfoil water parsnip
Inflated petiole	as a float on water	water hyacinth
Flytraps	capture insects	Venus's-flytrap sundew
Pitchers	capture insects	pitcher plants

Protective Devices of Plants

I. Against transpiration and temperature changes.

By rolling of leaves — *corn.*

By folding and rolling in bud — all plants.

By hairs — *mullein.*

By gums, waxes, or resins — *cabbage.*

By position of stomata — *under most leaves.*

By protection of stomata — *rubber plant.*

By fleshy growths — *agaves.*

By "sleep" movements — *legumes.*

By absence of leaves — *cactus.*

By shedding leaves — *deciduous plants.*

By erect position — *compass plants.*

By varying position of leaf — *rhododendron.*

By hugging the ground — *rosette plants.*

By subterranean growth — *tubers, bulbs, etc.*

II. Against animals, including man.

By hairs or wool — *mullein.*

By prickles — *rose.*

By spines — *cactus.*

By thorns — *honey locust.*

By stinging hairs — *nettle.*

By bitter secretions — *tomato.*

By poisons — *Jimson weed.*

By flinty epidermis — *grasses.*

By hugging the ground — *dandelion.*

By subterranean growth — *tubers, bulbs, etc.*

Reference Work

Collect plants mentioned in the foregoing tables and arrange them with reference to function. Draw.

XIII. PLANT IRRITABILITY

155. PHOTOTROPISM, OR RESPONSE TO LIGHT

Object. — *To study the effect of light on the daily movements cf plants.*

Apparatus. — A vigorous young sunflower or sweet clover plant.

Method. — Make observations on the plant early in the morning of a bright, sunny day, noting the position of the stem as well as that of its crown of leaves.

From time to time during the day observe it and take note of any change of direction. At evening, just before sunset, again make observations and again note the direction taken by leaves and stem. How does its morning position compare with that at evening? How may this be explained?

After sunset again make observations. Any new change?

On a cloudy day make similar observations on the same plant. Result?

Conclusion. — What may be given as the probable cause of these movements of plants?

Note. —The term *phototropism* has been used here because it is broader in its meaning than heliotropism. The former indicates the response to light of any sort. The latter implies response only to sunlight.

Where possible, experiments should be made with plants under artificial light.

156. SLEEP OF PLANTS

Object. — *To show the effect of light on the position and motion of plants.*

Apparatus. — Oxalis or clover plants in flowerpots. There should be two of each sort. Young, healthy plants are preferable.

FIG. 73. — Sleeping oxalis. (Photographed by A. H. Lewis.)

Method. — Place one plant in the strong sunshine for half an hour and the other in a dark closet.

Remove both plants to a shady place and compare their appearance. Now reverse the process, putting the plant which was in the light into the closet and the other in sunlight. After half an hour again compare. Result? Why?

Conclusion. — State your judgment of the cause of these movements.

157. SLEEP OF PLANTS

Object. — *To study the so-called sleep movement of plants.*

Apparatus. — Oxalis or any of the common leguminous plants, such as clover, sweet clover, desmodium, or locust.

Method. — If the plant is potted, place it in strong sunlight for half an hour. Observe the attitude of the plant.

Then place it in a dark closet for half an hour and again observe it. Notice the difference. If the plant is growing in the garden, study it by day and again by night, using a lantern. If the plant is large-leaved, like the locust, be careful to note just where the bending or folding of parts occurs.

Note. — Many plants have a swelling at the leaf base or petiole foot. This organ is known as a *pulvinus*.

Movements of such plants are thought to be caused by variation of sap pressure in the pulvini.

Suggestion. — Go into the field by night and study plants by the aid of a lantern. Many of the most familiar plants will be scarcely recognizable when seen in their sleeping condition.

158. RESPONSE TO CONTACT

Object. — *To learn something of the behavior of sensitive plants.*

Apparatus. — The best plant for this purpose is the greenhouse sensitive plant, *Mimosa pudica*, but the wild sensitive plant, *Cassia nictitans*, and the sensitive joint vetch may be used. The sundew and the Venus's-flytrap are too rare to be available.

Method. — Stroke a leaf lightly with a brush or the finger. Wait a minute and note the result. What happens?

If the mimosa is used, a very interesting result follows if the terminal leaflet is pinched.

Does the motion follow instantaneously like a reflex action in animals, or does it spread gradually through the leaf? Look for pulvini. Do you see any explanation of these phenomena?

Conclusion. — State what has been learned from this experiment.

159. RESPONSE TO CONTACT

Object. — *To learn something of how tendrils respond to stimuli of contact.*

Apparatus. — Any tendril-bearing plant, such as gourd, grapevine, or prickly cucumber.

Method. — Study the tendrils on a young shoot. Note how they are coiled. Examine a fully expanded tendril which has not yet come in contact with anything. Now bring a piece of cord or slender rod so as to touch it. Remove the cord and look at the tendril from time to time for ten minutes. If no change has occurred, repeat the experiment and again look for a response. Vary the experiment by hitting a fully expanded tendril two or three sharp taps, and by placing a string where it will rub gently across a tendril. Repeat the experiment with very young coiled up tendrils and again with old ones. Examine a tendril after it has seized a support. Note the spiral coiling. Is this alike from end to end? Can you find any part of the tendril which seems to be more sensitive than the remainder? If so, where is this special region?

Conclusion. — State in general terms what has been learned in this experiment.

Suggestion. — Compare tendrils of sweet pea, smilax, grape, pumpkin, and woodbine in order to find which respond most quickly. Compare the leafstalks of tropæolum and clematis with tendrils in the same way.

160. RESPONSE TO CONTACT

Object. — *To find out something of the movement of twining stems.*

Apparatus. — Several twining vines, such as morning-glory, hop, dodder, and cinnamon vine.

Method. — Study the various plants selected. Observe the direction in which they coil about a support. Do all twist in the same direction? If not, which turn from right to left, and which from left to right?

Uncoil a stem several turns and try to make it twine in the opposite direction. Result? See if you can make a stem which has not yet begun to twist, coil opposite to the way in which the other branches of the same plant tend to coil.

Conclusion. — State in general what this experiment has taught you.

161. RESPONSE TO CONTACT

Object. — *To learn something of the irritability of stamens of some flowers.*

Apparatus. — Flowers of barberry, mountain laurel, and almost any mint.

Method. — 1. Examine the position of the stamens and pistil in a cluster of barberry flowers. Now thrust a pin into the pistil and observe the result. Repeat the experiment with the same flowers and with other flowers.

2. Examine a freshly opened flower of laurel. Note the position of the stamens. Examine an older flower. What is the position of the stamens? Touch the stamens of the young flower. What happens? What would occur if a bee should enter such a flower? If possible, watch for a bee to visit the laurel flowers. What happens?

3. Study a mint flower in the same way. What movements are to be witnessed here?

Conclusion. — What may be inferred from these observations?

Suggestion. — If sundew plants are to be had, catch a tiny insect and place it near the middle of one of the leaves. The sticky hairs will hold it, and after a time the other hairs will bend slowly over and cover the insect. The Venus's-flytrap quickly closes and entraps a fly which may alight upon its surface. Sundews are not very abundant, but they are found in peat bogs and sphagnum swamps. The fly-trap is quite rare and is found only in the southern states.

Note. — For response to contact in roots see Experiment 64.

Find out by experiment: —

1. Do old parts respond to stimuli more or less readily than young ones? Find out by experiments on young and old tendrils.

Are very young tendrils sensitive? Are tendrils more or less sensitive by day or by night?

2. Study the young stems of a twining plant. Select two shoots of about equal size and vigor. Give one a cord to twine upon and the other none. Measure each at equal intervals of time. How do they compare in rate of growth? Measure one which projects beyond its support. Is there any relation between the rate of growth and the presence or absence of a support?

3. Test the sensitiveness of barberry stamens from fresh and from old flowers. Is there any difference? Reason? Do these stamens show sensitiveness in flowers not yet in bloom?

4. Select some fresh barberry flowers and place some in a cold place, as a refrigerator, for half an hour. Remove them and test the stamens immediately. What is the result?

Make similar tests with tendrils.

5. Let a tendril coil about a large support, as a lead pencil.

Count the number of coils. Carefully remove the pencil and insert a small wire in its place. What change takes place in the number of turns in the coil? What does this show?

Note. — To observe automatic movement in a plant place it under a bell jar or inverted battery jar, or support a plate of glass above it just so that it does not touch the plant. With a wax pencil used for marking on glass, and with the eye exactly above the plant, sketch the position of the uppermost pair of leaves. The sketch will thus become the orthographic projection of the leaves drawn.

After an hour make another observation, and if any change of position has occurred, sketch again as before. Continue observations and sketches until the fact has been established or disproved.

XIV. FLOWERS

162. FLOWER STRUCTURE

Object. — *To learn the parts of a typical flower.*

Apparatus. — Flowers of almost any common plant. Large, regular, simple flowers, such as those of the tulip, lily, rose, magnolia, and hollyhock, are preferable.

A simple magnifier, a knife, and a pin are handy.

FIG. 74. — Water lilies.
(Photographed by W. C. Barbour.)

Method.—Examine the flower and note that it is made up of one or more circles of parts. How many such circles do you find?

Describe the outermost circle (calyx), its color, number of parts (sepals), and the shape of each. (Such terms as wheel-shape, cup-shape, bell-shape, etc., will describe the calyx; and such terms as oval, spoon-shape, boat-shape, etc., will apply to the sepals.)

Describe the second circle (corolla). Of how many parts (petals) does it consist? Describe as before. These (petals and sepals) are called the non-essential organs. They are

for protection of the innermost parts and they often attract insects.

Now find the two kinds of essential organs which are found within the flower (stamens and pistils).

Conclusion. — State how many and what organs are found in a typical flower, naming them from outside towards the center.

Suggestion. — Find a flower in which one or more kinds of organs are missing (incomplete). Find one in which all

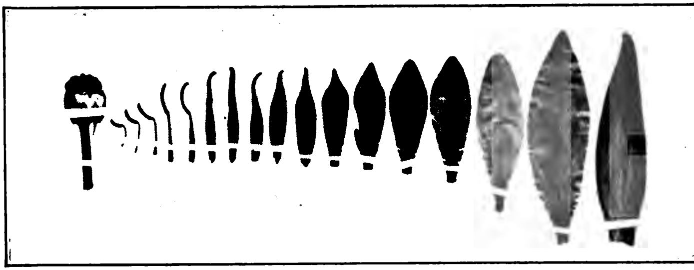


FIG. 75. — Parts of a water lily.

parts are present and of the same number (symmetrical) or a multiple of the same number. Find a flower in which some petals are larger than others (irregular). Find flowers in which the petals are grown together (gamopetalous) into one piece.

Is there any relation between the number of petals and stamens? (1) Make drawings of each flower studied, making the drawings to scale. Remove one of each set of floral organs, and (2) draw it enlarged, naming each part. (3) Draw a plan of each flower, showing the number and position of the various organs. (4) Draw a diagram of a lengthwise section through the center of each flower and show the insertion of each part on the receptacle.

Exercise

Procure a water lily, or a double tulip or rose, and carefully remove a part from each circle, laying the parts removed down in the order of their removal. Note how, as you proceed toward the center, the parts seem to change in shape. Do you find petals with anthers or stamens which are spreading out to form petal-like organs?

Suggestion. — Place the series of floral organs in a book and press them until thoroughly dry. Then mount them on a card, cover them with glass, and passe partout them with paper. Compare this series with similar ones of bud scales. What is the inference from these form studies?

163. SEX ORGANS OF FLOWERS

Object. — *To learn something about the reproductive organs of plants.*

Apparatus. — Any large perfect flower, such as tulip, Easter lily, wild crane's-bill, evening primrose, or hollyhock. If smaller flowers must be used, a simple magnifier will be necessary.

Method. — Remove the outer floral circles (calyx and corolla) and study what remains.

(*a*) *Stamens.* Remove a stamen from a fresh flower and examine it. Of how many parts is it composed? Describe it. *Draw.* Look for fine powder on the anther. This is pollen. The stamen is the male part of a plant. Pollen is the male or fecundating substance of the flowering plant.

(*b*) *Pistils.* Examine the organ which stands exactly in the center of the flower. This is the pistil. Of how many parts does a pistil consist? Some flowers have more than one pistil. How many are found in the flower studied? Draw a pistil, naming its parts *ovary, style, stigma.*

From an old flower remove the pistil. Carefully cut the lower part (ovary) crosswise. What is seen within? How many chambers (locules)? What is contained in the ovary? Note the partitions (dissepiments) which separate the carpels and the place where the immature seeds (ovules) are attached. This point of attachment is called the placenta, and it is through this that sap from the parent plant is conducted to nourish the ovules.

These young seeds or ovules will ripen and mature into young plants.

The pistil is the female part of the plant. From it come the young seeds. The ovary protects the immature seeds until ripe and ready to be cast.

Conclusion. — What parts of the plant are fitted for producing new plants?

Fig. 76. — Walnut flowers.

Fig. 77. — Willow flowers.

Note. — Stamens are the male part of a plant. They produce a powdery substance called pollen, which is necessary to the development of a seed. The pistils are the female part of a plant. They produce the ovules. The ovules never mature unless they receive the contents of the pollen grains from the stamens. Thus each little seed is the result of the combination of pollen with an ovule. The

parents of the baby plant or embryo are the stamens and pistils of the plants which produced them.

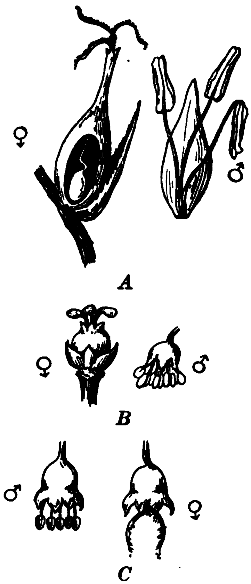


FIG. 78.— *A*, sedge; *B*, oak; *C*, sugar maple.

The sign ♂ stands for the male plant or animal and the sign ♀ indicates the female. In the accompanying illustrations are seen male and female flowers of several common plants.

When a flower possesses both the essential organs, it is said to be *perfect*. If only one kind of sex organs is present, the flower is said to be *imperfect*. If both kinds of flowers (staminate and pistillate) are found on one and the same plant, it is said to be *monœcious*, but when they occur on separate plants, they are said to be *diœcious*.

To which class do ailanthus, pine, corn, sheep-sorrel (*rumex*), ragweed, castor bean, willow, hazel, alder, chestnut, hickory, belong? Examine several flowers of Jack-in-the-pulpit and find three varieties: (1) all staminate, (2) all pistillate, (3) both sorts (polygamous). Squash flowers also are polygamous.

164. SEX ORGANS OF FLOWERS

Object. — *To learn what is meant by imperfect flowers.*

Apparatus. — Sterile and fertile flowers of any diœcious plant, for example, a cone-bearing plant (pine or spruce), and a magnifier.

Method. — (*a*) The male flower. Examine the whole flower (cone). Cut it open from end to end and note the attachment of the scales and the position of the stamens.

Remove one stamen. Note its form and the number of its pollen sacs. Where do these pollen sacs grow, on the upper or under side of the stamen? Can you find where

these pollen sacs split open for the casting of pollen? Draw two stamens, one with open and the other with closed anther.

Can you find anything resembling calyx and corolla?

What can you say of the size of pollen grains?

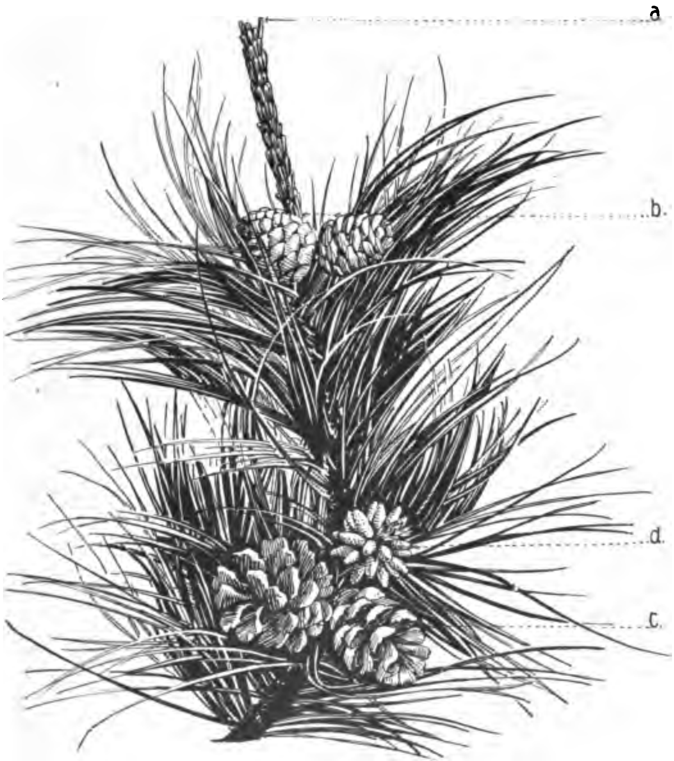


FIG. 79. — Corsican pine: *a*, pistillate flower; *b*, pistillate cones one year old; *c*, pistillate cone two years old; *d*, staminate cones.

(*b*) The female flower. Examine the cone and note the shape, size, color, and arrangement of the scales.

Why do the outstanding edges of scales project as they do?

Sketch the cone, showing the rows of scales as they stand.

Remove a scale and draw the upper and under views. Look for ovules (two small elevations near the base of a scale). Do you detect any means by which the pollen grains could be caught? Do you find anything corresponding to petals or sepals here? pistils?

Examine an older cone and determine the fate of these ovules.

Dip an old cone in water. What happens? Dry it out. What happens? What has the ability to open and close to do with dispersal of the seeds?

Note. — On account of the difficulty of obtaining the staminate flowers of pine trees the following plants may be studied equally well for work on imperfect flowers: any other cone-bearing plant, oak, willow, walnut, poplar, hickory, or chestnut.

165. POLLEN (optional)

Object. — *To study pollen.*

Method. — (*a*) Mount dry a few grains of pollen by shaking a ripe stamen over a microscope slide, and examine them with a low power.

Sketch a few grains as they lie scattered over the field in various positions.

To some fresh pollen on a microscope slide, add a drop of water. What effect does it have on the pollen grains?

Examine as many kinds of pollen as possible, especially that of dandelion, rose, tulip, pine, corn, milkweed, and evening primrose, where these can be had.

Which have large grains? small grains? dry grains? moist grains? Which show special means of flight? Which have special means for sticking to insects? What colors are most common in pollen?

(*b*) Place fresh pollen in a Petri dish and add a few drops of dilute sugar and water or honey. Cover it to prevent evaporation and examine it from time to time with the microscope. Look for very fine threadlike growths which come from the pollen grains. If a drop of eosin or methyl green is added, they will become more readily seen.

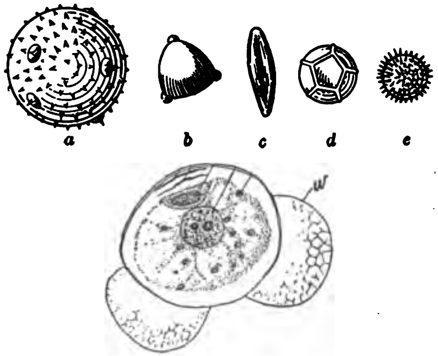


FIG. 80. — Pollen grains.

These are pollen tubes. When pollen germinates on the stigma of a flower of the same kind, the pollen tube penetrates the stigma, forces its way down through the spongy tissue of the style, until it reaches the ovary, and at last penetrates the micropyle of the ovule.

When this occurs, the living contents of the pollen grain fuse with that of the ovule, and the latter is then said to be fertilized. Hence this process is known as *fertilization* of the ovule.

It is not until this has occurred that the ovule begins to grow. With few exceptions, only fertilized ovules ever develop into seeds.

Note. — Since different pollens require different strengths of sugar, it is well in making this experiment to sow the pollen in Petri dishes containing sugar solutions of from 1 per cent to 15 per cent strength.

Definition. — In order that the ovules may grow they must receive pollen from the stamens. This is called *pollination*.

166. POLLINATION

Object. — *To find out whether pollen is necessary to the production of seeds.*

Apparatus. — Any blooming plants having large flowers or flowers whose stamens may easily be seen, a pair of sharp-pointed scissors, and paper bags.

Method. — Carefully remove the stamens from some flowers which are just opening, clipping off the anthers. Then cover the flowers with a paper bag, tying it so that no pollen can get in from any other flower and reach the stigmas. Treat other flowers in the same way, but do not cover them with a bag. Thus the first flowers can receive no pollen, while those of the second sort are open to the visits of insects and winds. After ten days remove the bag and compare the two flowers.

Conclusion. — What must be inferred as to the necessity for pollen in the production of seeds?

Note. — Experiments in pollination are seldom successful when undertaken within the house. This is due to absence of insects and to shelter from the winds. If experiments must be made in the laboratory, pollination must be done by hand, and care must be observed to get pollen which is just ripe and to place it on a stigma which is ready to receive it.

All such experiments succeed much better when made in a garden where winds and insects have free play.

167. POLLINATION

Object. — *To illustrate pollination by insects.*

Apparatus — Flowers of toadflax, four-o'clock, iris, cypripedium, or honeysuckle. The experiment is best made in the field where the plant is growing.

Method. — Study the flower, making note of its color, odor, and peculiarities of form. Hunt for nectaries and special structures, such as spurs, nectar guides, etc., which aid insects in their work of pollination. Look for special devices which prevent the entrance of unwelcome visitors.

FIG. 81. — Flower and moth.

Take a position near the plant and await the coming of an insect visitor. Observe what insects come, how they alight upon the flower, how they enter it, and whence they

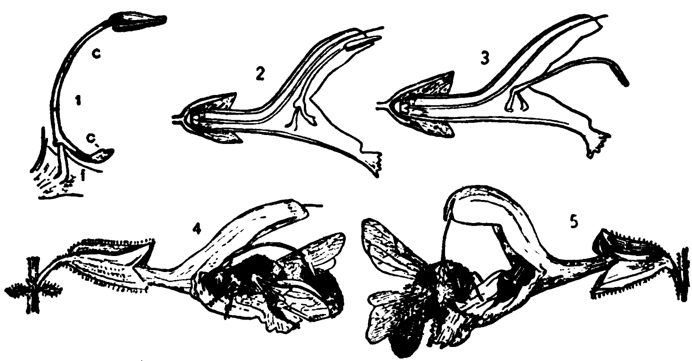


FIG. 82. — Pollination of *Salvia glutinosa*. 1, a stamen. The upright column to the left of *f* is the filament. *c*, *c*, the connective, anther bearing above and sterile below. 2 and 3, longitudinal diagrams of a young flower, showing the anther in its natural position in 2, and pushed down by a bee by pressing on the lower part of the connective in 3. 4, a bee visiting a younger flower; the anthers pushed down upon its back. 5, a bee visiting an older flower; the style having become elongated and pendent touches the bee's back. After KERNER.

go on leaving it. Can a bee enter and leave a flower without touching the stamens and pistils?

Conclusion. — State how the flower studied makes it possible for pollen to be transferred from flower to flower.

Suggestion. — Observe butterflies, humming birds, and hawk moths as they fly about. See if you can discover by what means they reach into a blossom. Examine goldenrod in the field and look for various kinds of beetles which usually infest these plants.

How is the shape of the corolla of Jimson weed (Fig. 81) fitted for insect visitors? Is it adapted to pollination by bees?

168. POLLINATION

Object. — *To learn how flowers are formed to permit the winds to carry pollen.*

Apparatus. — Flowers of grasses, corn, or plantain.

Method. — Study the flowers, making comparisons with those in the previous lesson. Is there any conspicuous color, odor, or nectar which is likely to attract insects? Are the flowers open or closed? Do the stamens project, or are they hidden deep in a corolla tube? Is there much or little pollen, and is it sticky or dry? If the tassel at the top of a cornstalk is shaken, a large amount of pollen will usually be obtained.

Conclusion. — In a single sentence state how the wind-pollinated plants differ from those pollinated by insects.

Suggestion. — Examine some pine pollen with a microscope. How are the pollen grains specially fitted for flight?

Note. — Some years ago, after a strong south wind, the streets of Washington, D. C., were found covered with a yellow powder, which, on examination, was found to be pine pollen. The nearest pine forests from which it could have been wafted are in North Carolina, several hundred miles distant.

169. POLLINATION

Object. — *To learn what is meant by self-pollination.*

Apparatus. — Flowers of closed gentian, fringed milkwort, or the common cleistogamous flowers of the blue violet.

Method. — Examine the flower to be studied. Cut open the ovary and find the seeds. Does the plant receive pollen from any other plant? If not, whence comes the pollen which has made the ovules mature into seeds. If the flower does not open, the pollen cannot have been borne on the winds or brought by insects. From what source must it have come?

Conclusion. — What is self-pollination?

Suggestion. — (*a*) Look for cleistogamous flowers at the root of violet plants. Notice that such flowers are lacking in the color, odor, and nectar which are so abundant in the ordinary flowers of the violet.

(*b*) Can a plant be pollinated artificially? Hint: Having removed the stamens from a freshly opened flower, fill a camel's-hair brush with pollen. Gently brush it over the stigma and then inclose it in a paper bag. This will prevent any other pollen from getting on. After ten days remove the bag and note the result.

(*c*) Make the same experiment, using pollen from other kinds of plants. What result? Does it make any difference whether the pollen is fresh or old?

(*d*) Is the stigma as receptive at one time as another? Examine hollyhock flowers on the same spike. How do the stamens of the upper flowers differ from those of the lower ones? How do the pistils differ?

(*e*) Walk in a field or pasture where there is English plantain growing, or observe any mint or mallow. Are all

the heads alike? Select one from which stamens are projecting and tie a colored thread about it or otherwise mark it. At the same time mark one from which the stigmas are projecting. After a day return and examine each stalk which has been marked. What change? If no change is noted, come again a day later and again make observations. What do you learn from this regarding pollination of plantain? Can plantain fertilize itself? Give a reason for your answer.

Fig. 83. — Columbine. Pollinated by insects. (Photographed by W. C. Barbour.)

(*f*) Take your station in a garden near a bed of bright or sweet-scented flowers and make note of what insects visit these flowers. Towards evening watch near a honeysuckle or trumpet creeper. By what creatures are these flowers visited? Catch a hawk moth and find its long proboscis by means of which nectar is extracted from flowers.

Catch a bee and examine the legs to find pollen in the pollen baskets.

Note. — Hybrids are formed by crossing plants, that is, by pollen of one plant fertilizing the ovules of another plant. The new plant may have the characteristics of both parents.

Sometimes the offspring combines desirable qualities of both parents, and sometimes undesirable qualities predominate.

In this way the plant breeder can improve his plants by a careful selection of parent plants and a destruction of those which show undesirable qualities.

Thus sweet corn and pop corn have been produced from the primitive wild field corn of the Indian.

In recent years the seedless apple and many other new fruits and flowers have been produced by crossing and selection.

Variation

Note. — Examine a large number of plants of the same sort with a view to their points of difference. The leaves of dandelion plants show very great differences in outline, and those of the arrowhead are so different in form that there are seldom two leaves alike on the same plants (hence the name *Sagittaria variabilis*).

Exercise. — Select two plants which show as much difference as possible. The oxeye daisy and Indian corn are good for this purpose.

(*a*) The Oxeye Daisy

Compare the two plants. Are they alike in size? Are the leaves alike in size and shape? Make note of any differences in leaf outline. Compare the stems as to thickness and strength. Look for differences in habit of growth. Are there any differences in surface characteristics, such as smoothness, roughness, pubescence, etc.? Compare the flowers as to number of heads, size, number of ray flowers to each head, and color and position of the floral parts. Try to find two oxeye daisies which are exactly alike in all these qualities.

What do you conclude as to absolute likeness among flowers?

(*b*) Indian Corn

Procure several ears of corn and note the following points: shape of the ears, whether cylindrical, tapering, blunt, etc.; color of the grains, size of the grains, evenness or regularity of arrangement of the grains; color of the cob, etc.

FIG. 84. — 1, seed ear of corn; 2, 3, 4, types of ears harvested.
(Year Book, 1902, U. S. Dept. Agr.)

Count the number of grains to each row. Do all ears agree in this? How many rows to the ear? Are all ears alike in this? What is the average number of rows per ear? Are all ears from the same plant alike in this?

Compare ears of sweet corn, pop corn, and different varieties of field corn, and tabulate the results.

(*c*) Sports

Examine any large plant, such as a rose bush, or branches from a large shrub or tree. Look for branches which are different from the remainder of the plant. Such branches will not often be found. They are known as *sports*.

Many new forms of fruit and varieties of flowers have been produced by propagating such sporting branches by means of cuttings. Sporting branches are common on coleus plants, which may be made to produce some very odd color effects by making the cuttings at the right time.

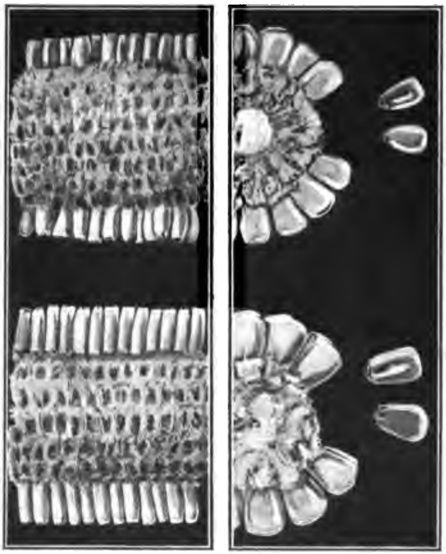


FIG. 85. — Variation in size of cob and length of kernels.
(Year Book, 1902, U. S. Dept. Agr.)

The famous and always popular Bridesmaid rose originally sprang from a sport in one of the rose houses of Mr. Frank L. Moore of Chatham, N. J. From that one branch have descended all the Bridesmaid roses now so abundant in the rose houses. The seedless orange was propagated from a sport.

Suggestion. — Study plants of the same kind growing under different conditions of moisture, also plants having submerged, floating, or aërial leaves. How do they vary in form? Study plants in sun and shade. Study the effects of rich and poor soils on character of foliage and habit of growth.

(See tables of leaf modifications (pp. 171, 172), also discussion of fertilizers (pp. 105–108).

Queries. — From your knowledge of plant breeding how

would one set about to produce a double daisy? A very large daisy? A large-leaved or downy-leaved daisy?

How should one proceed in order to develop a variety of corn having more or less than the normal number of rows of grain to each ear? How might sweeter and larger kernels be produced?

How has the seedless apple been developed? How can it be propagated when once produced?

XV. SPECIAL EXERCISES ON TYPICAL FLOWERS

170. TRILLIUM

This is a particularly good flower for beginners, since its structure is so simple and all its parts are so large and distinct. It may be found in damp, rich woods, in spring, almost everywhere.

Method. — Procure if possible one entire plant, so as to describe all parts. Does it spring from a rootstock or bulb? Reasons for your answer. Are the roots fleshy or fibrous? Study the aërial portion. Is the stem monocotyl or dicotyl in structure? Reasons for your judgment. What is the arrangement of leaf? Number, veining, shape, and outline of leaves?

FIG. 86. — Trillium.
(Photographed by W. C. Barbour.)

Note length and position of the flower stalk. Of how many sepals does the calyx consist? Their shape and color? How many petals? Their shape, color, and size? How many stamens? Describe them. Remove all parts and study the pistil. Is it simple (consisting of only one carpel) or compound (composed of several united carpels)? *This can be told by the number of stigmas, styles, or lobes of the ovary.*

Make drawings as follows: —

1. The entire plant.
2. The plan of the flower.
3. A sepal, a petal, a stamen, and the pistil × 3.

171. THE IRIS

Blue flag is common along streams and marshes and fleur-de-lis is abundant in gardens. Most of these flowers are to be had only in spring, but the *Tigridias* may be cultivated in gardens late in the summer.

Fig. 87. — Iris.
(Photographed by W. C. Barbour.)

Method (*Field*). — Study the plants in the field, noting the erect habit of growth, shape, and position of leaf, character of the soil where they grow. Procure an underground part and examine it. Is it root or stem? Reason for your answer. *Draw.* Note the way in which the leaves overlap (equitant). Do these plants in general occupy any definite position with reference to the sun; that is, are they in any way what are known as compass plants? If so, account for it.

Method (*Laboratory*). — Study a bud. How do the floral organs overlap in the bud? *Draw.* Study a flower. How many floral circles can you find?

Describe each circle. (When the two outer circles are alike in color, they are spoken of as a *perianth* instead of calyx and corolla.) Of how many parts is the perianth composed? How do these parts differ in position? In other respects? What appendages are found on one set which are not found on the other? Can you suggest any use for this? Note the long, slender tube where the parts of the perianth are united. *Draw* the flower.

Remove the perianth and study the essential organs. *Draw.* How are the stamens placed relative to the stigmas? Is self-pollination possible in such a flower? Reason. Where is the nectar secreted? Try to discover how pollen can be transferred by bees from flower to flower. Where is the ovary? Cut a flower lengthwise through the center. *Draw* the section exposed.

172. EVENING PRIMROSE

Evening primrose may be found in dry fields, roadsides, and waste places, and sometimes in gardens. It opens late in afternoon about sunset and remains open all night, closing next day about ten o'clock A.M. or earlier. It often remains open longer if the day be cloudy. When opening, it often makes a distinct sound like an explosion.

Its fragrance is peculiar, having a suggestion of black pepper.

Method (*Laboratory*). — Are the flowers solitary or in clusters? If clustered, describe the cluster. Remove one flower. Has it a stalk (pedicel)? If so, describe it. Describe this flower, calyx, corolla, stamens, pistils, giving number, size, shape, character of the pollen, and other characteristics.

Where do the old flowers grow? The buds? Can you determine how many flowers will be borne on this cluster?

For study of pistil use the oldest blossoms, and for stamens the buds which are about ready to burst.

Split open the long tube and see if you can find any trace of nectar in its depths. Its object? Draw a flower, top view, showing the arrangement and number of the parts; also a view of the split corolla. Draw one stamen and a

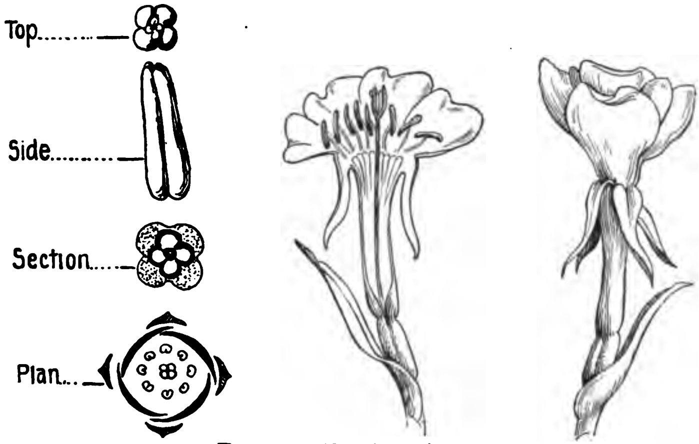


FIG. 88. — Evening primrose.

view of the ovary. Cut open a mature ovary crosswise and make out the attachment of the ovule. Can you discover any lines or seams (sutures) where the fruit will split when it becomes ripe? Draw pollen highly magnified.

Method (*Field*). — Take your station near an evening primrose plant just about sunset and listen for the explosions which accompany the opening of the flowers. What insects visit these flowers? See if you can discover how they extract the nectar.

Note. — For comparison study willow-herb (*epilobium*). Both evening primrose and willow-herb are good for autumn as well as spring classes, since they usually blossom until frost.

173. THE BUTTERCUP OR ANEMONE

There are many species of buttercup, and they differ so in habit of growth that no exact outline can be laid down for their study. The leaf is very different in different species and the stem may be bulbous, erect, creeping, etc. But the flowers are all essentially alike.

What is the character of the stem? Is it erect, creeping, bulbous, etc.? Is it smooth or rough, silky or downy? Are the leaves opposite or alternate? How are they divided? Draw a leaf. Are the upper leaves like the lower ones? If not, draw one of each sort. Study a flower and draw one. Is it complete or incomplete? Describe each kind of organ found.

How many sepals? Their shape? How many petals? Their shape and any other characteristics? Remove a petal and draw it. Look for a scale or nectary at or near its base. Its use? How many stamens? How many pistils? Describe one pistil. Has it all parts? If not, which part is missing?

Are the petals opposite or alternate with the sepals? Draw a section through a flower, showing all parts in position. Draw a plan of the flower, showing each floral circle.

In a bud or very young flower notice how the petals are arranged with reference to each other. Are any of the petals entirely outside the others (imbricate), or how are they arranged? Indicate this on the floral plan.

Note. — The buttercup is the representative of a great family of plants, the crowfoot family.

Suggestion. — Study the flowers of clematis, anemone, hepatica, columbine, and larkspur for comparison. Most

of them are spring flowers, but clematis and larkspur can be found blooming in autumn.

Make out a list of characteristics common to all these plants.

174. THE STRAWBERRY, GEUM, OR POTENTILLA

The strawberry, like the buttercup and sweet pea, belongs to a great family of very useful plants.

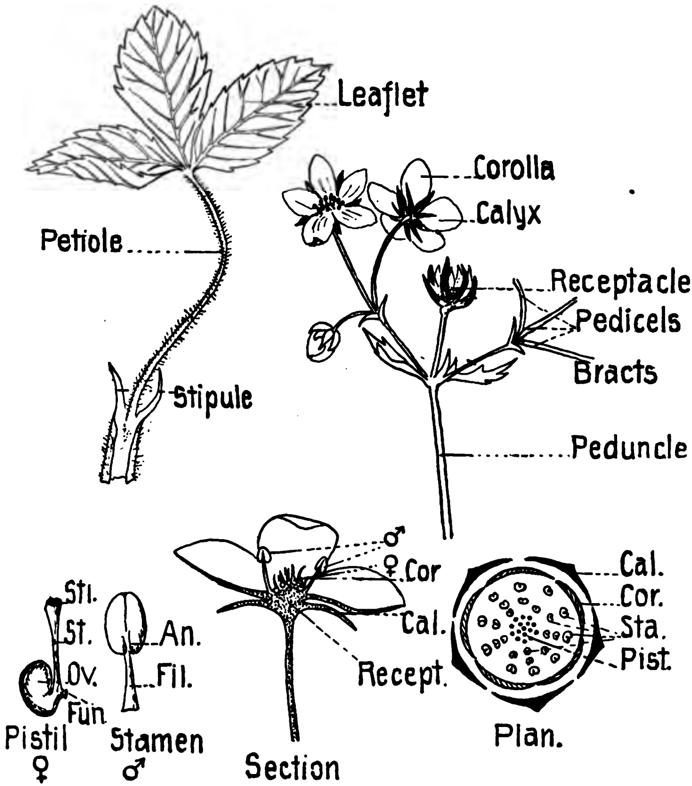


FIG. 89. — The strawberry.

Roses, peaches, pears, cherries, and many other very common plants are members of the same order.

Method. — How does the strawberry plant spread? Make a sketch, showing a runner. Draw one leaf and name the following parts: petiole, stipules, blades (leaflets). How many leaflets are there?

Are the flowers solitary or in clusters? Is the inflorescence definite (ending in a flower) or indefinite (ending in a bud)? Examine a flower cluster (cyme) and draw a diagram to show the kind of inflorescence.

This flower seems to have ten sepals, but such is not the case. There is a whorl of five bracts just outside the calyx. How many sepals? Petals? Are they separate or united? How many stamens? Pistils? Remove a petal and draw it. Remove a stamen and a pistil and draw them greatly enlarged. Study the oldest flower in the cluster and see what becomes of the pistils.

What is the origin of a strawberry? What part of the plant is eaten? What are the little yellow points on the surface of a ripe strawberry which give it its name?

Make drawings of a section through a flower, a plan of the flower, and a section of the fruit.

Suggestion. — Compare apple blossoms and roses with strawberry blossoms. Wherein are they alike? In what respects do they differ? Compare raspberry flowers and fruit with those of the strawberry in a similar manner.

175. MUSTARD OR ANY OTHER CRUCIFER

Mustard is a common weed which is a representative of a very important family of plants. Radish, turnip, horseradish, cabbage, and many other food plants are related to it.

Method. — Draw the entire plant if it is not too large. If it is too large, make drawings of basal leaves, stem leaves, flowers, fruit, and inflorescence.

Draw one flower greatly enlarged. Dissect a flower and draw one of each set of parts. How many sepals and petals? Are they alike in size? How are they arranged when seen from above? The plants of this order are called crucifers (cross bearers). Why is the name appropriate? Are the stamens alike in length? If not, how many are there and how do they differ?

Select an old ovary and cut it crosswise. Draw the section, showing the attachment of the ovules. From a very old pod find out how they break open and how the seeds are scattered.

Taste of the seeds or green stems. Describe the peculiar flavor.

Note. — In spring the cresses are abundant. During summer horse-radish and mustard are very common in bloom. Sweet alyssum, candytuft, and wallflowers may be found in gardens and hothouses. Shepherd's-purse is a common weed belonging to the same family, but its flowers are too small to be studied without the aid of a magnifier.

176. A LILY OR AMARYLLIS

Any liliaceous flower will do for this exercise. Tulips, lilies, day lilies, yuccas, star-of-Bethlehem, and hyacinths are common in gardens and are cultivated for ornament.

Onions, garlic, leeks, and asparagus are esteemed for food.

Method. — Study any of the above plants as in previous exercises.

Some spring from rootstocks, others from bulbs. If from the former, study and make out the nodes, roots, and re-

duced leaves (scales). If from the latter, determine whether the bulb is solid (corm) or scaly.

Study the stem, noting the smooth skin, rather prominent nodes, and absence of annual rings (monocot). Study the leaf. Its veins are of what kind? What type? (See Ch. XII.)

Fig. 90. — Lilium superbum.
(Photographed by W. C. Barbour.)

What is the number of floral circles? How many parts in each? Draw the whole flower, one of each of its parts, a plan of the flower, and a section to show insertion of parts.

Make a cross section of the ovary, showing placentation. *Draw.* From your observation, will the pod split (dehiscent) or remain closed (indehiscent) when it ripens? How

many chambers (locules) in the ovary? Is the flower symmetrical or unsymmetrical? regular or irregular? perfect or imperfect? Give reasons for your answers.

Note. — A study of a liliaceous flower will give one more difference between monocotyl and dicotyl plants, namely — *The floral organs are always in threes or multiples of three.*

Compare arrowwort, iris, spiderwort, and lilies in this respect.

177. JACK-IN-THE-PULPIT OR SKUNK CABBAGE

Method. — Following the same general plan as outlined in the preceding exercise, answer the following questions: —

FIG. 91. — Jack-in-the-pulpit.

What is the habitat in which this plant grows? What are the form, position, and venation of the leaf? What is the nature of the stem (monocotyl or dicotyl)? Give reasons for your answer.

From what underground part does the plant spring? Describe it. Is it a root or a stem? Give reason for your answer. Describe the roots. Cut a slice from the corm (underground part) and touch it to the tongue. Do not chew it or take any portion into the mouth. Only touch it to the tongue. Describe the taste. After having tasted it, what do you think of the

common belief that this plant was eaten by the Indians? Taste a corm after cooking it. Does heat have any effect on it? The name Indian turnip is often applied to this plant. Test it with iodine and see whether starch is present.

Study the inflorescence. The flowers are situated at the base of a club-shaped *spadix* and are surrounded by a broad leaflike *spathe* which arches over the flower cluster. Turn back the spathe and examine the parts within.

What is the color of the spathe? Are all spathes colored alike? Are the flowers perfect or imperfect? Have they calyx and corolla?

Cut open a spathe, removing a part of the lower side so as to expose the essential organs.[1]

Make drawings of (1) the plant, (2) a spathe, side view, (3) front view, (4) the spadix with spathe removed.

Suggestion. — Observe the plant all through the season. Of what use is the spathe? What becomes of the spathe? What insects visit this flower? What kind of fruit does the ripened cluster of pistils become? When does it mature? What is its color? Gather some of the ripened fruit in October or November and plant them in damp soil in winter. Their germination is very interesting.

Note. — Jack-in-the-pulpit corms may be dug in autumn and planted in a window box where they will bloom in winter. For other plants having a spathe and spadix study the common water arum, skunk cabbage, golden club, and sweet flag.

They are all spring flowers. Many strange and beautiful spadicious plants are to be seen in conservatories.

[1] A study of many specimens of Jack-in-the-pulpit will discover the fact that some are all staminate, others are all pistillate, and some, by far the greater number, contain flowers of both sorts. Plants having all three kinds are known as *polygamous*. See also Note, Experiment 163.

178. LILAC, FORSYTHIA, OR PRIVET

Method. — Make drawings of the flower, top view, showing number, shape, and position of petals, and position and number of stamens.

Draw side view so as to show the calyx, the corolla tube, and the general shape of the corolla. Split open the corolla between two of the lobes and draw the interior view, showing the insertion of the stamens, the anther cells, and the lines where they will split when mature.

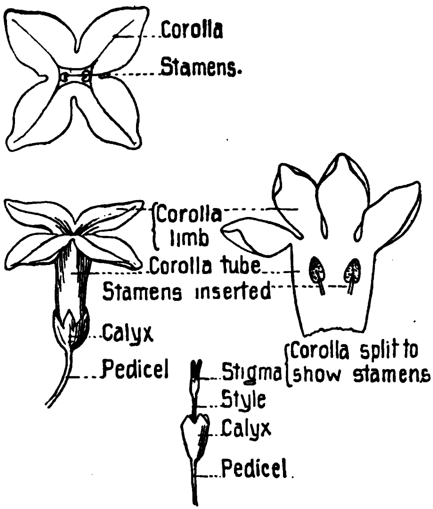


FIG. 92. — The lilac.

Carefully pull off a corolla and draw the pistil as it stands in the calyx. Cut away one side of the calyx and show the ovary.

Answer the following questions: —

How many petals? Are they free or gamopetalous? How many stamens? What is their position relative to the petals? How many stigmas and how many parts has the ovary?

This is a good example of what is known as a symmetrical flower. It has sepals 4, petals 4, stamens 2, pistils 2, *i.e.* one consisting of two carpels.

What renders this flower attractive to insects?

Suggestion. — For comparison study flowers of forsythia,

Virginia fringe tree, and privet. These shrubs are all members of the same order of plants.

179. SWEET PEA, LOCUST, OR LUPINE

These plants belong to a great family of plants, the Leguminosæ, to which beans, clovers, medick, vetches, mimosas, and many other plants belong.

Method. — How does the pea vine climb? What is the shape of its stems? *Draw* one of its peculiar leaves. How do its stipules differ from those of most plants? How are the uppermost leaflets modified? For what purpose? Are the tendrils sensitive?

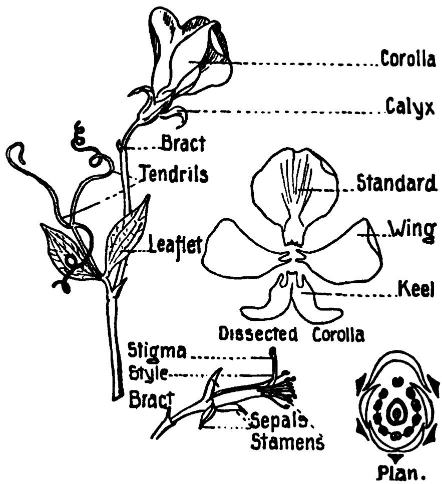


Fig. 93. — The sweet pea.

Describe the flower. Is it solitary or clustered? Of how many parts does the calyx consist? Are they alike in size? Of how many petals does the corolla consist? Is it regular or irregular? Give reasons for the answer. *Draw.* Remove the petals one by one and arrange them in order. *Draw.* How many stamens are there? What is peculiar about the stamens? *Draw* the essential organs in place. *Draw* a plan of the flower showing the position of the various organs. Remove the stamens and expose the pistil. An old flower or one which has faded will be best for this. Find

all parts of the pistil. What is peculiar about the position of the style in relation to the ovary? Is the pistil simple or compound? Give reason for your answer. *Draw* pistil. Procure a ripened pod and compare it with a pistil. What parts of the pistil persist?

Note. — This form of corolla is often called *papilionaceous*, a word that means butterfly-shaped. Why?

Query. — Is this flower regular or irregular? Symmetrical or unsymmetrical? Perfect or imperfect? Complete or incomplete? Give reasons for your answer.

180. VIOLETS

Violets are so well known and there are so many species that it is well to have as many different species as possible in the class.

Method. — Draw a typical leaf. How are they rolled in

FIG. 94. — Blue violet.

the bud? Draw views of the flower, front and side, showing all parts.

Dissect a flower. Find the *spur*. Is it a special part or a modification of some petal? Reason for your answer. Bite off the tip of the spur and taste the nectar. Find two

FIG. 95. — Yellow violet.

hornlike projections from the two lower stamens which secrete the nectar.

Are the stamens united? Remove the stamens and draw them showing their apparent attachment (syngenesious).

Do the stamens turn their anthers towards or away from the pistil?

Find flowers without petals down near the root of the violet. These may be found all summer, developing in great numbers and producing a vast quantity of seeds. See Suggestion, Experiment 169.

181. TOADFLAX OR BUTTER AND EGGS

Toadflax is a common weed of roadsides and fields. Its bright color and curious two-lipped flowers are always attractive to the student.

Method (*Laboratory*). — Make a drawing of the entire plant, showing its strict habit of growth, position, and shape of leaves on the stem, and kind of flower cluster (spike).

Remove a flower and draw it enlarged. Notice the peculiar shaped corolla (labiate or two-lipped). Of how many petals is each lip composed? Compare the upper and under lips as to color, surface, and shape. Take the flower between the fingers and pinch it gently. What happens? Look into the open throat of the corolla and see how many stamens and pistils can be seen. Cut open a corolla, being careful not to injure the essential organs. *Draw.* How do the stamens compare in length? Their number?

From your knowledge of pollination, how is this plant able to give and receive pollen? Examine the spur as was suggested in the exercise on the violet. Does it contain nectar? Draw a bud, showing how the petals are folded in the bud. Draw a stamen enlarged. Remove the corolla and draw the essential organs, naming all parts shown. Draw one of the fruits (capsules). Cut an ovary crosswise and draw it, showing the placenta, seeds, ovary walls, partitions if any, etc. From a ripe or nearly ripe capsule, remove a seed and examine it with a magnifier. What peculiarity have they?

Method (*Field*). — Study toadflax in the field. What insects visit this flower? How do they enter it? Are there any special structures which aid a bee to get into the corolla?

Can a fly get in? How about small insects like ants which are fond of sweets? Having seen a bee enter a toadflax blossom and come out again, examine a flower, paying special attention to the position of stamens and pistils. In the light of these observations, how are these flowers adapted to insect pollination.

Note. — Other plants which resemble the toadflax are the mulleins, gerardia, foxglove, turtlehead, and snapdragon. All are good for laboratory exercises. Mullein is noted for its leaves, which are covered with branching hairs. Foxglove is a beautiful garden flower from which the poison digitalis is obtained.

182. A MINT

The characteristics of the mint family are so definite that any of the following plants may be selected as typical: catnip, peppermint, spearmint, gill, skull-cap, salvia, and heal-all.

FIG. 96. — A mint.

Method. — Study the plant as a whole, noting position of the stem, whether erect, creeping, etc., and *shape* of the stem. What is the *leaf arrangement?* Bruise a leaf and inhale the odor. What is the flower arrangement (inflorescence)? Remove a flower and determine: —

1. Form of calyx and number of sepals.

2. *Form of corolla*, number, attachment, and cohesion of the petals.
3. *Number*, attachment, and *other peculiarities* of stamens.
4. *Number of ovaries* and *stigmas*.

Note. — All members of the mint family are alike in shape of their stems, arrangement of their leaves, shape of their flowers, and number of their ovaries. Their stamens differ in number, but they agree in being unequal in length; that is, 2 long and 2 short or 4 long and 2 short (didynamous or tetradynamous). Their foliage is usually odorous, for example, peppermint, spearmint, hoarhound, pennyroyal, catmint, and ground ivy. Among autumn flowers the salvias of the gardens are good for study.

Suggestion. — Study any mint in the field as it is suggested to do with toadflax. What insects visit it? How is the flower adapted to receive the visits of insects? How are the essential organs arranged for giving and receiving pollen?

Note. — The splendid scarlet salvia of the parks and gardens and the common coleus plants are good mints for any season from May to November.

183. THE SUNFLOWER, ASTERS, OR GOLDENROD

The sunflower belongs to the largest of all families of flowering plants. This family is known as the Compositæ, because their so-called flower is composed of many small flowers closely packed together, the whole cluster resembling one flower.

Method. — A sunflower should be examined as a whole, noting, first, the circles of green leaflike organs (bracts) which imitate a calyx; second, the single circle of yellow, strap-shaped flowers which appear to be a corolla; and last, the broad disk covered with the dark brown tubular flowers where stamens and pistils are seen in simple flowers.

Note which of the disk flowers are open and which are still buds. How does the blossoming proceed, that is, from circumference to center, or the reverse? Remove a disk flower and a ray flower. Compare them and draw each enlarged. Do you find any part that represents the pedicel? The calyx? Of how many petals is the corolla formed? How may the number of petals in a ray flower be determined?

Examine a flower just opened and find out how many stamens it has. What is peculiar about their anthers? Examine a flower nearer the edge of the disk. How many stigmas has it? Are the ray flowers fertile (having essential organs) or sterile (without essential organs)? If sterile, of what use are they to the plant?

Gather a few grains of pollen on a microscope slide and examine it dry with a low power. Draw a pollen grain. From an old flower head remove one of the disk flowers which has matured, and examine it. Find the calyx which forms the teeth at the top of the ovary. Remove all the flowers from the disk and find the small bracts (chaff) which cover it. Can you determine how many such chaff scales accompany each disk flower? Study the naked disk, noting the pits or scars where flowers and chaff were attached.

Note. — Other composite flowers are the daisy, aster, fleabane, goldenrod, and black-eyed Susan. Most of these are autumn flowers.

184. THE DANDELION, CHICORY, OR HAWKWEED

The dandelion is another plant whose flowers grow in a composite head.

Method (*Laboratory*). — To procure dandelion plants, the student should be provided with a sharp spade with which

to dig up the strong taproot which penetrates the ground to a considerable depth. In addition to a whole plant, there should also be a supply of buds, flowers, and ripened fruits. A magnifying glass is a necessity.

How does the root adapt the dandelion to withstand the cold and the efforts of the gardener to exterminate it? Taste of the root. How does the dandelion withstand the ravages of root-eating animals?

What can be learned of the *stem?* What advantages has a so-called stemless plant? What of the leaf arrangement? Account for the rosette form. How does this prove an advantage to the dandelion? What effect does such a growth have on other plants, such as grasses, which grow close by? Break off a leaf. Describe the sap, its taste, color, etc. *Draw.* Account for the shape and peculiar margin of the leaves.

Study a bud, making note of the many circles of bracts which surround it. What is their position in a bud, in an expanded head, in the withered flower, and in the ripe fruit?

Examine the flower. Has it ray flowers and disk flowers like those of the sunflower? Wherein does it differ? Remove a flower and study it with a magnifier. Find the ovary, its crown of very delicate bristles (pappus), and the other parts of the flower. Study and draw as in the preceding exercise. Remove some pollen and examine it dry with a low power of the microscope. *Draw.* Select a fully expanded ball of ripened fruit. Blow it gently to see the fruit (achenes) float away. Study a single fruit and draw it. Examine the receptacle after all the fruits have been blown away. Note the pits where they were attached. *Draw.* Compare with lettuce, chicory, and cynthia.

Suggestion. — Find out what use is made of dandelion root (taraxacum). How do gardeners exterminate this weed? Its use in spring as salad and greens is well known.

Method (*Field*). — Make observations on a dandelion plant from day to day, taking note of the following points: —

(*a*) Character of soil where it grows.

(*b*) Variation in size and shape of leaf due to habitat.

(*c*) Leaf arrangement (rosette) affording large surface in small space.

(*d*) Absence or shortness of stem affording protection from browsing animals and from cold weather.

(*e*) Effect of the leaf arrangement in monopolizing space to the exclusion of other plants.

(*f*) Behavior of the plant, especially the action of the involucres in opening and closing the flower in different stages and under different conditions of light and weather.

(*g*) Mark a bud which is about to open by tying a colored thread about its peduncle (flower stalk). Note when it opens and closes, also how many days it continues to open and close.

(*h*) When the ball of fruit expands, observe the manner of seed dispersal.

(*i*) Carefully dig up a plant and study the long, sturdy taproot.

There is another group of composite plants whose flowers are all tubular. The commonest ones are ironweed, the thistles, and bonesets.

Suggestion. — Study a plant of burdock or thistle as in the other exercises on composites. Draw a head, showing the outer involucre of hooked or prickly bracts. Cut a head lengthwise and draw the section exposed. Remove a flower and draw it greatly enlarged.

When the fruit has matured, draw one of the beautiful tufted achenes of a thistle. If burdock is used, remove one hooked bract and draw it enlarged.

185. INDIAN CORN

This plant is best studied in the field, but if corn can be grown in a school garden, it will be equally good. If studied in the laboratory, an entire plant is desirable, also young and old ears, ripe ears, and a supply of fresh sterile flowers from the tassel.

Method. — The great number and character of roots, the aërial, adventitious, or so-called *brace* roots which spring from the lower nodes for the purpose of supporting the plant, are always seen. The smooth, jointed stem so characteristic of monocotyls is not to be overlooked. The long parallel-veined leaves also prove the monocotyl nature of the plant.

(*a*) Study the tassel as a flower cluster, then remove one fresh flower and find its parts. Has it calyx and corolla? How many stamens to a flower? Do you find a pistil? Is there any organ where the pistil ought to be? Draw one flower, showing its pedicel and other parts. Name the organs which resemble sepals (*glumes*). Do the glumes stand opposite each other, or are they overlapping? How many glumes are there? Draw a stamen. Describe a stamen. Shake a corn tassel. What can be said of the amount of pollen? Is it dry or sticky? Examine it with a microscope. Draw a pollen grain. How does it compare in shape with other kinds of pollen?

(*b*) Study a very young ear. By what is it covered? How are the husks arranged? Cut an ear open from end to end and study the arrangement of parts.

Examine an older ear from which the silk is beginning

to project. Carefully strip back the husks and expose the kernels without breaking off the silk. Trace one thread of silk from end to end. From what does it come? Where is it attached to the kernel?

Examine the exposed end of a corn silk, using a magnifying glass. Describe its surface.

Query. — How is a corn plant provided against self-pollination? What advantage is there in having the staminate flowers at the top? Why do corn flowers lack color, odor, and nectar? Why are the tassel flowers open? Account for the amount of pollen. Do ears and tassels of the same plant mature at the same time?

Note. — Oaks, chestnuts, birches, alders, and sedges have the sterile and fertile flowers on different parts of the same plant.

XVI. EXPERIMENTS WITH FLOWERS

186. FUNCTION OF THE PERIANTH

Object — *To find out the function of the perianth of a flower.*

Method. — From any large flower bud, carefully remove the calyx and corolla, thus exposing the essential organs to view. Do the same with a flower just opening. Mark both with a tag or bit of colored cord. From time to time observe the flowers.

When fruit matures, note which if either produces the most seed. Also which produces the best quality of seeds, a mutilated flower or one which has been left intact.

Note. — Tulips and other large flowers are best for such experiments.

Suggestion. — Find out whether the position of a flower has any relation to seed production. Do this by selecting some large irregular flower, as a nasturtium (tropæolum), and carefully twist the stalk halfway round so as to bring the upper petals below and the under petals above. A pansy or papilionaceous flower is good for such experiments.

Note (1) whether such flowers have the power to right themselves, (2) whether insects visit them as readily as those which have not been inverted, and (3) whether they develop their seeds as well. Why or why not?

187. EFFECT OF LIGHT

Object. — *To demonstrate the effect of light on flowers.*

Apparatus. — A blooming oxalis plant.

Method. — Place the plant in the sunshine. When the flowers are wide open, remove to a dark closet for one hour. Bring the plant out and examine the flowers. How do they differ from their original condition.

Return the plant to the darkness and again note result.

Repeat the experiment, using artificial light.

Conclusion. — State the effect of light on oxalis flowers.

Suggestion. — Expose night-blooming flowers, such as four-o'clock, moonflower, and evening primrose, to strong light. Will they respond?

Query. — Why do night-blooming flowers usually remain open during cloudy days? What relation can you discover between the behavior of flowers and leaves at night.

Note. — The opening and closing of flowers cannot be attributed wholly to presence or absence of light. There are many plants which open their flowers at night. Of such are the night-blooming cereus, night-blooming water lilies, evening primrose, four-o'clock and moon vine. Many other plants open their flowers by day and close at night. But by far the great majority of flowers, when once open, remain so until fertilized. Then they wither and die.

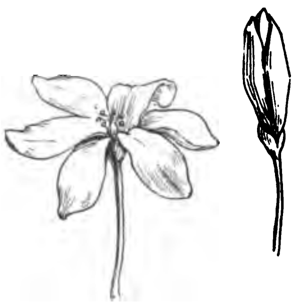
The time of opening and closing seems rather to be a specific characteristic.

188. EFFECT OF HEAT

Object. — *To demonstrate the effect of change of temperature on flowers.*

Apparatus. — Flowers of crocus, tulip, or star-of-Bethlehem, and a thermometer.

Method. — Select some buds which are about to open. Note the temperature of the air. Put them in a cold place, such as a refrigerator, or in a stoppered bottle which is immersed in a pail of ice water. The latter is better, since the light is not shut off as it is in a refrigerator. Repeat the experiment, using an open flower instead of a bud. Remove the bud to a warmer place and note the result. Try the exercise with different flowers. Are all equally sensitive? Make the experiment with only slight changes of temperature. Procure, if possible, a flower of night-blooming cereus or any other night-blooming plant. Cut the flower from the stem at night when it is in full bloom and transfer it immediately to a cold dark place. It may be kept open for a long time in this way. Flowers of Phyllocactus latifrons have been kept open for thirty-six hours in this way.



12° C. 22° C.

FIG. 97. — Star-of-Bethlehem.

Conclusion. — State what is to be inferred as to the effect of temperature on opening and closing of flowers.

Query. — From your observations, which do you think is the more potent cause of these phenomena in flowers, light or heat? Give reason for your answer.

189. RESPIRATION OF FLOWERS

Object. — *To find out what is given off by flowers.*

Apparatus. — Some half-open flowers of such plants as dandelion, daisy, or elder, two wide-mouth bottles, corks, and materials for testing gases.

Method. — Note first that there is nothing but air in the bottles. Place the flowers in one bottle and cork tightly for ten or twelve hours. Remove the cork and test the gas with a burning stick, with limewater, etc., to determine whether it is oxygen or carbon dioxide. Test the contents of the other bottle which has been corked and kept as a control. Result?

Conclusion. — State what is given off by flowers.

190. FLOWERS GIVE OFF HEAT

Object. — *To demonstrate the evolution of heat by flowers.*

Apparatus. — Fresh flowers of dandelion, aster, elder, a wide-mouth bottle, perforated cork, thermometer, sealing wax or paraffin.

Method. — Fill the bottle loosely with the flowers. Pass the thermometer through the cork and insert it in the bottle. Close the opening with wax to prevent escape of air and set it away for observation. Watch the thermometer. Does the temperature rise or fall? How can this be accounted for? In what way is the result of this exercise connected with that of the preceding Experiment?

Conclusion. — State the result of your observations.

XVII. TYPICAL FRUITS

191. CORE FRUITS

Object. — *To learn the structure of a core fruit.*

Apparatus. — Two apples and a knife.

Method. — Study the outside of the apple. Find the stem end, the blow end. What parts of the flower are still found attached to the fruit?

Cut one apple from stem to blow end and examine the section exposed. Note the *skin*, *flesh*, *fibrous line*, *core*, and *carpels* full of seeds. Find also where and how the seeds are attached. Draw the section, naming all parts.

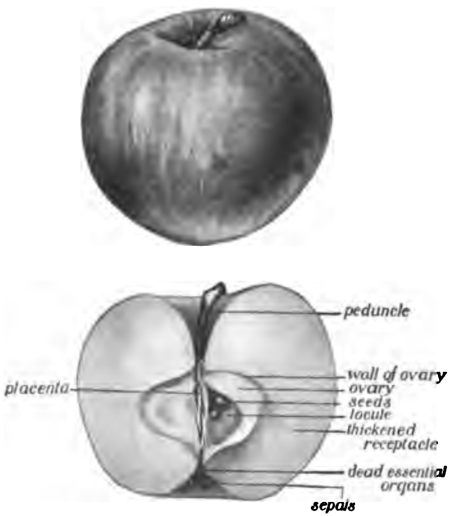


Fig. 98. — The apple.

Cut the other apple crosswise through the center. Find all parts mentioned above.

Conclusion. — Describe the structure of a core fruit, naming each part from outside to center.

Suggestion. — Compare apples with pears, quinces, haws, and the fruit of mountain ash.

192. STONE FRUITS

Object. — *To learn the structure of a stone fruit.*

Apparatus. — A peach and a knife.

Method. — Study outside as before. Then cut through flesh to the pit and remove one half.

Note character of the flesh, the stone, etc. Remove the stone and crack it. How many coverings has the seed?

Conclusion. — Describe a stone fruit as in preceding Experiment.

Suggestion. — Compare peach with plum, cherry, apricot, date, and olive.

FIG. 99. — The peach.

193. PULPY FRUITS

Object. — *To find out the characteristics of a pulpy fruit (berry).*

Apparatus. — A tomato and a knife.

Method. — Study the outside as in the two preceding Experiments. Are there any remains of the flower left on this fruit? How can you account for the scar opposite the stem? What part of the flower adheres to the stem? Cut a tomato crosswise. Into how many sections is it divided? What can you say of the number, attachment, and location of the seeds?

Conclusion. — Describe a berry, having a tomato in mind as a typical berry, stating what you can of the character of the skin and the number and location of the seeds.

Suggestion. — Compare the tomato with the grape, gooseberry, and currant, which are typical berries; also with the orange, melon, etc., which are modified berries.

194. DEHISCENT FRUITS

Object. — *To learn what is meant by dry fruits, and how they scatter their seeds.*

Apparatus. — Pods of beans, peas, locust, honey locust, catalpa, or any other dry dehiscent fruit.

Method. — Study the fruits selected and determine how they split. Some open on one seam only, others on two seams, and still others in three or more places.

Examine several old pods which have split and note whether they are still flat or twisted.

Do you see any advantage in having the valves twist as they spring apart?

Hang up several ripe pods not yet open and let them remain for some time. When they split, note the result. What becomes of the seeds?

Conclusion. — State what a dry fruit is and how the seeds are scattered.

195. SEED DISPERSAL

Object. — *To learn some ways in which a plant scatters its seeds.*

Apparatus. — Maple keys, balsam or jewelweed plants in fruit, and burdock or clotburs, desmodium, and milkweed.

Method. — (*a*) Study the maple key to get an idea of the formation of its wing and the number of seeds it contains. Throw one into the air and see how long it takes to fall to the ground. Of what use is the wing? Compare it with dandelion, milkweed, and ailanthus fruits.

(*b*) Select a branch of balsam or jewelweed having full-grown pods. Touch one and note its behavior. How far can the balsam pod throw its seeds. Compare it with wistaria pods and with the so-called squirting cucumber.

(*c*) Examine the fruits of burdock and clotbur. How are they fitted for being scattered? Throw one against a piece of cloth. Result?

Compare them with sticktights, beggar-lice, and other similar fruits.

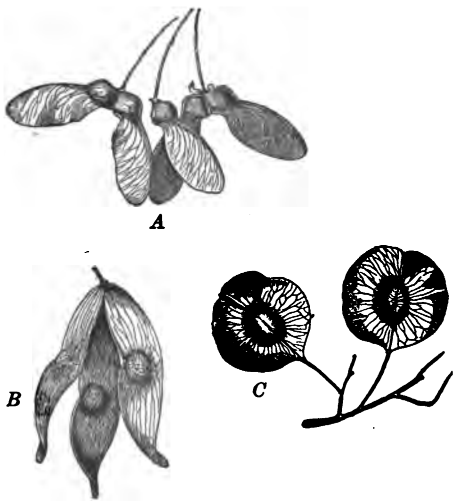


FIG. 100. — *A*, maple; *B*, ailanthus; *C*, Ptelea.

(*d*) Study all the others in like manner, making out the peculiar method of seed dispersal employed by each.

Queries. — How are geranium seeds scattered? How does the basswood tree scatter its seeds? How do you account for the distribution of such fruits as apples, peaches, and edible nuts which have no wings or barbs or the explosive power to expel their seeds?

Suggestion. — Examine the wool of a sheep or the tail of a cow and find if any seeds are clinging there. After

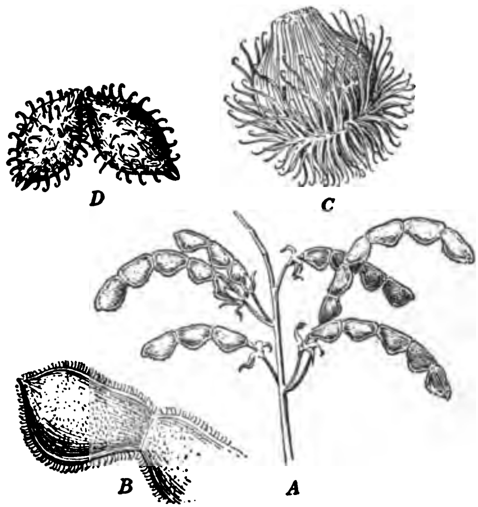


FIG. 101. — *A*, sticktights; *B*, sticktights, magnified; *C*, burdock; *D*, cocklebur.

a walk through the woods in summer or early fall what fruits will be found clinging to your clothing?

196. SEED DISPERSAL

Object. — *To demonstrate seed dispersal by explosive fruits.*

Apparatus. — Witch-hazel fruits which are ripe but not yet bursting, wide-mouth bottles, damp sand or moss, and formaldehyde.

Method (*Laboratory*). — Gather the witch-hazel fruits and place them in the bottles of damp sand or moss to which has been added enough formaldehyde to prevent decay. A few drops of 4 per cent solution is sufficient. When you desire to show the phenomenon of seed dispersal by explosive

FIG. 102. — *A*, violet; *B*, squirting cucumber; *C*, cranesbill; *D*, witch hazel.

action of fruit, take one of the specimens from the preparation jar and place it where it will dry out.

When dry the capsule valves will close up and the seeds will be thrown to a considerable distance.

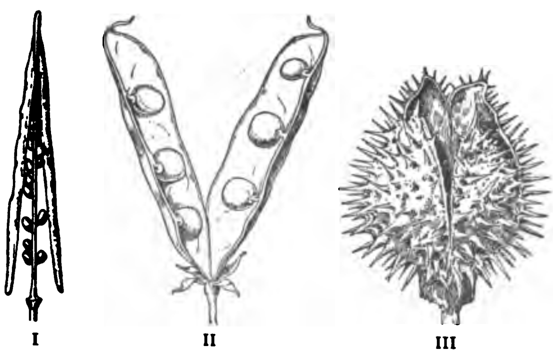


FIG. 103. — I, celandine; II, pea; III, jimson weed.

Table Showing Methods of Seed Dispersal

Seed Dispersal	1. By winged fruits.	maple ash elm ailanthus
	2. By winged seeds.	catalpa trumpet vine pine
	3. By hooked fruits.	clotbur burdock sticktight
	4. By tufted fruits.	thistle dandelion geranium
	5. By tufted seeds.	milkweed cotton althea
	6. By tailed fruits.	clematis avens anemone (patens)
	7. By explosive fruits.	witch-hazel jewelweed wistaria
	8. By buoyant fruits.	coconut balloon vine bladder nut
	9. By edible fruits.	berries cherries garden fruits
	10. By edible seeds (by man)	nuts cereals
	11. By brittle stems.	Russian thistle panic grass "tumbleweeds"
	12. By breaking of a falling fruit due to force of the fall	Brazil nut

Method (*Field*).—Go into the woods, fields, and parks and make a collection of as many examples as possible to illus trate seed dispersal.

Bring them together and mount, label, and classify accord ing to the method of dispersal represented.

Make drawings of each type found and supplement specimens with pictures.

Query. — How are poppy seeds scattered? How can you account for the occurrence of poison ivy along the fences bordering country roads? How are cedar trees so often found along roadsides at quite regular intervals as if planted by man?

Suggestions. — (1) Test various common fruits for the nutrients. Sugar will naturally be found in most sweet fruits. Which fruits contain protein, starch, oils? Which have the greatest amount of water?

(2) Test ripe and unripe fruits of the same sort such as green apples and ripe apples. How do they differ in their food content?

197. SAP FLOW IN FRUITS

Method. — Find out where the sap flows in a fruit, by making an experiment similar to experiments on sap flow in roots, stems, and leaves. Cut off and place with the peduncle (stem or fruit stalk) immersed in eosin or methyl green dye. After a few hours, cut open the fruit and see what structures have become stained with the color. Does it reach the seeds? What light does this exercise throw on the use of the hilum of seeds?

Note.—Cucumbers, gourds, okras, and other garden fruits when unripe will give excellent results.

Reference work. — (1) Do fruits require sunlight in order to ripen?

Pick two of each sort of several unripe fruits. Place one of each in a dark place and the other where it will receive the sunlight. Temperature and other conditions must be the same for both samples.

After a week's time, examine both fruits and note the difference.

(2) Do fruits require air in order to ripen?

Repeat the foregoing experiment, using fruits, some of which have been previously coated with vaseline to close the pores in their skins.

(3) What is the function of the fruit skin or epicarp?

Compare peeled with whole fruits both ripe and unripe. Does the removal of the skin have any effect on ripening? On retention of sap? On hastening or retarding decay?

(4) Examine fruit skins with a microscope. Do they possess stomata?

Query. — Why do gardeners often pluck unripe tomatoes and lay them where the sun shines to ripen?

XVIII. CRYPTOGAMS

Introductory Note

The following Experiments on a few typical seedless plants are added for the purpose of giving the student a general idea of what is meant by the so-called flowerless plants. Most of these Experiments are such as may be undertaken without the aid of a compound microscope. The unaided eye is able in most cases to see the structures alluded to, and a simple magnifier is all that will be required.

As every well-equipped school is provided with at least one compound microscope, the use of the latter is recommended.

198. ALGAE (pond scum)

Pond scum (spirogyra) is one of the commonest water plants, where it often abounds in still or slow-flowing streams. It is easily recognized by its bright green, silky threads, which form dense tangles. At times they throw off great masses of gas which gives them a frothy appearance, hence it is often called "frog spittle."

Object. — *To study growing algae.*

Method. — Place a mass of pond scum in a tall beaker (*a*) or preparation jar and set it in the strong sunlight.

Place another (*b*) similar mass in darkness or diffused light. After one hour place the jars side by side and compare their contents. Where is the green alga in (*a*)? In (*b*)? Do you discover any reason for this? Change the bottles, placing (*a*) in shade and (*b*) in strong sunshine for

another hour. What change has now taken place in each jar? Why?

Arrange an apparatus as in Experiment 145, putting the pond scum below the funnel. Now place it in strong sunlight. What comes from the plant? When a test tube is full, remove and test with a lighted stick. Is it nitrogen? Hydrogen? Carbon dioxide? Oxygen? Give reason for your answer.

Now select a small portion of the plant. Remove it with your fingers and place in a white earthen dish with enough water to cover it. How does the plant feel?

Examine the threads of pond scum as they lie in the dish. Of what do they consist? Do the threads branch or fork? Examine with a magnifying glass and you will see that the threads are built up of little cylinders placed end to end. These are cells, and the fiber is made up of a string of such cells. Try to find the end of one of the threads. Does this end cell look like the others? If not, how does it differ?

To what is the green color due? In coarse plants the arrangement of this coloring matter (chromatophores) may be made out.

At certain seasons, one may find places where the threads are of different color, and sometimes no green color will be found for several cells. Two threads may also be found so joined as to form a sort of ladder. Look for these things.

What effect does the presence of many such plants have on the value of drinking water?

Suggestion. — Mount a thread of pond scum in water and examine with a low power. Note the cell wall, the clear contents of each cell, and the green spiral within (Fig. 115). Examine many such threads and search for the end cell. Is it like all the others? If not, how different?

Suggestion. — Extract the chlorophyll from a mass of spirogyra by placing it in a beaker and covering it with alcohol.

What change occurs in the color of the alcohol? Remove some of the plant and compare it with some which has not been immersed in alcohol.

Refer to Experiment 149. Why is the color so different here from what it was there?

Query. — Does spirogyra make starch? Does it contain starch?

199. REPRODUCTION IN POND SCUM

Object. — *To observe conjugation in spirogyra.*

Method. — In autumn procure a supply of spirogyra and, having placed some in a shallow dish, examine with a magnifier in search of the parallel filaments which have formed the ladderlike structures referred to in the foregoing Experiment. Remove such to a slide, cover with a cover glass in water, and carefully examine with a low power. Look for the various steps in reproduction: —

1. The ordinary cylindrical cells with their spiral chromatophores.
2. Cells from separate filaments which have produced knobs projecting towards each other.
3. Cells in which these processes have met but not yet united.
4. Cells in which the processes have united and their dividing walls have ruptured to permit the contents of one cell to flow into the other.
5. Empty cells whose contents have gone into the conjugating cell.

6. Zygospores, or oval masses which have formed out of the united contents of the two cells.

Notice the thickened wall which forms about the zygospores.

Note. — Reproduction is effected in two ways in spirogyra: (*a*) Asexually, that is, by pieces breaking off and continuing to grow. (*b*) Sexually, that is, by the forming of zygospores through the union of contents of neighboring cells. The process is known as *conjugation*. The sex elements are different from those of flowering plants in being *alike* in appearance.

200. PLEUROCOCCUS

This common alga is found on the north side of stone walls, old fences, and tree trunks. It is usually more abundant near the ground, but sometimes is to be found on old roofs. It gives a green color to whatever it grows on, becoming brighter in damp weather.

Object. — *To study the structure of pleurococcus.*

Method. — Procure bits of bark or old wood showing green color, note powdery appearance on dry surfaces; place in a damp chamber where they will remain moist. What change of color follows? Set in a warm place, preferably in the shade. Remove some of the green material and mount it in a drop of water. Examine first with a low power and later with a higher ($\frac{1}{6}''$ objective) noting:—

1. The shape of the cells.

2. Dividing cells as shown by pairs and clusters which are still united.

3. Can you distinguish between the cell wall and cell contents?

4. Can you determine the number, shape, etc. of chloroplasts?

5. Can the nucleus be seen?

Let a drop of iodine solution flow under the cover glass. Look for starch test. What effect does iodine solution have on the nucleus? From observations on the plants, determine how reproduction is effected.

Note. — This method of reproduction is known as *direct cell division*. The cell simply cuts itself in two by forming a partition through the center. Each new cell is known as a *daughter* cell. The original cell is called the *mother* cell. After cell division the daughter cells remain loosely attached for some time while they proceed to grow. Either one or both of the daughter cells will again divide, thus forming groups of three, four, etc., in clusters. Draw single plants, dividing cells, also any clusters which may be observed.

201. VAUCHERIA OR GREEN FELT

This plant is most abundant in muddy pools and ditches, where it forms in masses resembling felt. It is also found growing on damp earth and on moist surfaces of flowerpots.

Object. — *To study the structure of vaucheria.*

Method. — Examine the pads noting the color, texture, feeling, etc. Under the microscope make out the coarseness of the filaments. Do they branch regularly or irregularly? Do the filaments show any light relation? If so, what? Is a filament uniform in diameter or does it vary? Is the filament divided into cells by cross partitions? Is the protoplasm uniformly colored?

Look for *rhizoids*, or colorless rootlike outgrowths, *chloroplasts*, *oil globules*, *nuclei*, and a central *vacuole*. Using iodine solution, determine whether starch is present.

Look for sex organs, (*a*) the large oval oögonium containing an egg. Look for the pore through which sperms

can enter at fertilization. Where is this pore situated? (*b*) The short bent antheridium or male reproductive organ.

Let the material remain in a warm place and cover to prevent drying out. Under favorable conditions the *zoöspores* or sperms will develop and may be studied under a high power. They escape from the antheridium and swim about by means of pairs of delicate *cilia* or lashes. A drop of iodine solution is needed to show these organs.

Fertilization is effected when a sperm swims into the pore of the oögonium and fuses with the egg.

Look for the ripened egg or oöspore within the oögonium. How do the walls and contents differ from that of an unfertilized egg?

This method of reproduction is known as *heterogamy*, because the sex elements are unlike, namely, eggs (♀) and sperms (♂).

202. BREAD MOLD

Object. — *To study the growth of bread mold.*

Method. — Select two wide-mouth bottles. Mason fruit jars with rubber rings and screw tops are best.

Place a piece of bread or banana skin or a cold boiled potato in each jar, and leave it open to the air of a kitchen, pantry, or cellar for five or ten minutes. Then screw on the covers tight, after having added a few drops of water to insure a damp atmosphere within.

Now plunge one jar into a kettle of boiling water and let it boil for a few minutes. Remove it and stand both jars in a warm place for several days.

Which jar first shows signs of mold? Why? How long before the other jar shows mold?

What does this teach us regarding the effect of heat on molds?

Why do canned fruits as a rule not become moldy? If one should find mold in a fruit jar, what inference can be made as to the method of canning? Open the jar in which there is a good crop of mold and quickly plunge in a lighted candle. Does it burn or go out? What does this show as to what is given off by molds?

For laboratory work, lay a slice of stale bread or some slices of cold boiled potato on a dish. Dampen or add a sponge saturated with water and cover with a bell jar. When a good crop of mold has appeared, remove the bell jar and examine the colony of plants. Note color, size, smell, and general appearance of the plants. Notice the tiny threads (hyphæ) which form a delicate network all over and through the bread. Look for other hyphæ which stand up at right angles to the surface. How do these upright threads terminate? (Sporangium.)

Observe these parts with a magnifier. How do the sporangia differ in color? How may old ones be distinguished from young ones?

Make mold cultures of all manner of food stuffs and compare them. See if you can grow bread mold on cheese or meat. Also the reverse.

203. MOLDS

Object. — *To show the development of different molds in food materials.*

Apparatus. — Several plates, bell jars or tumblers for covers, and an assortment of foods, such as bread, cheese, orange peel, banana, etc.

Method. — Moisten each article and place it on a plate. Cover it with the bell jar and set it aside in a warm, dark place. Observe any changes which may take place from day to day. When molds appear, examine them carefully. Where color begins to show, the spores are beginning to ripen. Examine them with a magnifying glass. How many different species can you find? Do the different kinds appear on the same or on different substances?

204. MOLDS

Object. — *To show the mycelium of a mold.*

Apparatus. — Test tubes, fruit juice, or any liquid culture medium.

Method. — Partially fill the test tubes with the fruit juice and drop into each a few mold spores taken with a needle from a moldy substance. Set them in a place favorable for growth and make observations daily with a magnifier. Note the minute threads which are sent forth from the spores. These are called *hyphæ.* Study the way in which they spread outward and downward into the fruit juice. The mass of branching and interlacing threads is called the *mycelium.*

How do the parts above the surface differ from those below? Which ones bear spores?

Mount the mycelium in a drop of water and study it with a low power.

205. MOLDS

Object. — *To demonstrate the presence of mold spores in the air.*

Apparatus. — Petri dishes, nutrient solution (see page 257) making it slightly acid by addition of hydrochloric acid or fruit juice until it gives litmus a red color.

Method. — Expose the dishes in various places for two or three minutes. Then cover them and set them away for the molds to develop.

Make the exposures in different places, as cellar, pantry, parlor, etc. Make some exposures out of doors and others in the house.

After three or four days, what results are to be seen?

Conclusion. — What does this show concerning the prevalence of mold spores in the air?

206. MOLDS

Object. — *To show that there are mold spores in dust.*

Apparatus. — Petri dishes as before.

Method. — Over one Petri dish shake a dry dusting cloth or feather duster. Over another, shake a damp dust cloth. Over a third shake a rug. Into a fourth drop a bit of dirt scraped from a crack in the floor.

Close all the preparations and set them away for development of molds. After three or four days note the result.

Conclusion. — What may be inferred as to the occurrence of mold spores in dust? From your experiment which is better to use, a dry or a damp dust cloth? Why?

207. MOLDS

Object. — *To learn some of the conditions favorable to growth of molds.*

1. *Moisture.* Place a piece of wet bread and a piece of dry bread side by side on a plate and cover them with a bell jar. After a week study the preparations. On which one does mold develop best? Inference?

2. *Temperature.* Prepare three Petri dish cultures. Sow

them with a liberal supply of spores, close them, and place one in a very cold place, the second in a warm place, and the third where it is quite hot. After one week, bring the preparations together and compare results. Inference?

3. *Light.* Prepare two Petri dish cultures as before, placing one in a dark or semidark place, and the other on a window sill where it will receive direct sunlight. After one week bring them together and compare. Inference?

4. *Air Supply.* Make two Petri dish cultures, placing one under cover and the other where the air can freely blow over it. After a week, bring them together and compare them. Set a culture on which a fine growth of mold is growing where the wind can blow over it. What result? What may be inferred from this experiment?

Note. — The canning of fruit depends largely on exclusion of molds. The heating of the fruit is designed to kill molds which may have found access to the fruit. The cans are closed quickly while the contents are still hot so that no spores can get in. The sealing must be air-tight to prevent molds from getting in before the fruit is eaten. In spite of all these precautions, sometimes molds will find entrance and spoil the fruit.

208. FUNGI

Object. — *To study a mushroom.*

Mushrooms may be found in rich woods, fields, meadows — wherever there is abundant decaying vegetable matter.

These plants are saprophytes, that is, living on decaying substances. They are important economic plants for the reason that they aid in the removal of dead vegetation.

Method. — Draw the fungus after having studied it to make out the following parts: the cap (umbrella or pileus), the column (stipe or stalk), the gills or flat plates which extend

from center to circumference underneath, the veil or delicate membrane which stretches across from the rim of the cap to the *annulus* or ring which adheres to the stipe, and the mass of rootlike fibers at the base of the stipe called mycelium.

FIG. 104.—Mushroom. (Photographed by A. H. Lewis.)

Cut a vertical section through the center of the cap and down through the stipe. Draw the section and name all structures seen.

What is the color of the under side of a mushroom? Are the young and the old ones of the same color? Do all the gills extend from center to circumference? Are they attached to the stipe?

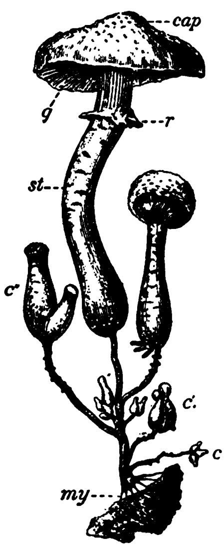


FIG. 105.—Mushroom: *my*, mycelium; *c*, *c'*, *c''*, young buttons; *st*, stipe; *r*, ring; *g*, gills.

Spore Prints.—Cut off the stipe of a fresh young mushroom close to the pileus. Lay it down upon a piece of white paper. Invert over it a tumbler to prevent the wind from blowing away the spores.

After a few hours, carefully remove the tumbler and lift the pileus. What do you find on the paper where the mushroom lay? Beautiful spore prints may be made in this way. Dark spore fungi show up best on white paper, but pink spores or yellow or white ones are best seen on black paper.

To fix a spore print a fixative such as is used by artists may be employed, but the force with which an atomizer throws the spray will usually spoil the print.

A better way is to make the prints on very thin Japan paper and float it on a dish of fixative or mucilage until the latter penetrates the paper through and through. Then dry it and mount it on a card for reference.

Another way of fixing is to spray a fixative over the paper first and then get the spore prints while the preparation is still moist.

Caution. — Too much cannot be said concerning the danger of tasting unknown fungi. Beware of any fungus

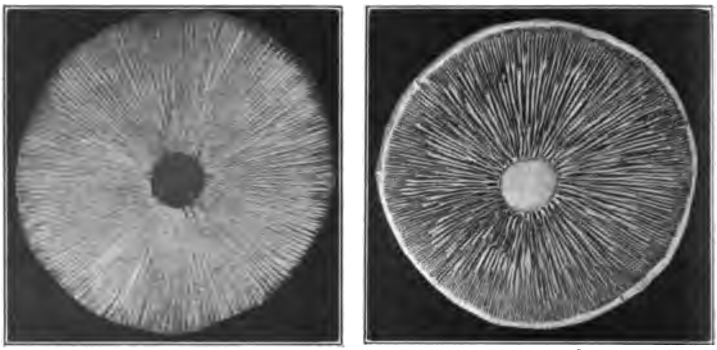


FIG. 106. — Spore print and spore-bearing surface.
(Photographed by A. H. Lewis.)

which has a *cup* at its base. As a rule, any highly colored or strong-smelling fungus or one having a milky sap is not regarded as wholesome, although there are exceptions to all these rules.

209. FUNGI

Object. — *To study shelf fungi.*

Procure as many different kinds of shelf fungi as possible. They are always found growing upon the dead branches of trees or upon fallen logs.

Make a note of the kind of tree on which they are found growing, and if possible secure a portion of the bark and wood at the point where the fungus is attached.

In general three types of shelf fungus will be found. Their chief difference will be the character of the under surface. In some this surface will be found covered with minute pores, in others there will be a beautifully corrugated surface, and in the third class this region will be found covered with teeth or points.

FIG. 107. — Shelf fungi. (Photographed by W. C. Barbour.)

Method. — Study the specimen and determine its color, feel, and texture. Draw upper and under aspects. Answer the following questions: On what tree did the specimen grow? What are its color, texture, and smell? Is there any way by which its age can be determined? Is there any system about the arrangement of the ridges, pores, or teeth on its spore-bearing surface?

Cut a specimen from upper to under surface. How far do the pores extend? Draw a portion of the section. Does the fungus grow continuously or by seasons? Give reasons for your answer.

Examine the base where the fungus is attached and see if you can find any roots or other connection with the tree. Examine some of the wood and also a specimen of sound

wood of the same kind. How do they differ in look, strength, softness, and other qualities?

Note. — Fungi propagate by spores which are so light as to be easily carried by the winds. When discharged from the parent fungus, they float away on the winds. If any favorable locality for growth is found, such as the exposed end of a broken branch or a fallen tree, these spores promptly germinate and begin their work of destruction. The tree becomes permeated with the fine cobweblike fibers, and when mature, they produce the shelves. Whenever a tree is seen to bear these fungi, it should be promptly cut down and burned to prevent the spread of the disease.

Logs and old lumber which are affected with fungi ought to be burned.

Suggestion. — Procure some fresh mushrooms with a portion of the soil in which they are found growing.

Repeat Experiments 140–144 with them to find out if they transpire water. Repeat Experiments 145 and 152 and 153 to find out whether they perform the same work as green plants.

Examine a portion of the delicate skin covering of the fungus with a microscope. Do you find stomata?

210. A MOSS PLANT

Object. — *To learn the characteristics of the spore-bearing stage of a moss.*

Apparatus. — Any moss when in fruit, a hand magnifier, a pin.

Method. — From a tuft of moss, carefully remove one of the plants. If the specimens are dry, they may be freshened up by plunging them into hot water for a minute before studying. Of how many parts does a moss plant consist? Describe each. Examine one leaf with the magnifier. Do you find any veins such as are found among seed-bearing

plants? Have they leafstalks? Draw. Find the capsule at the top of the stem (stipe). Does this capsule spring from the end of the stipe, or is it borne on the side?

FIG. 108. — Two common mosses.

Find a capsule which bears on its top a very loose and delicate cap (the calyptra). This cap is often shed, but will surely be found on some of the plants. Remove the calyptra and sketch. Examine the capsule and draw it greatly enlarged.

FIG. 109.—A common moss plant (*Polytrichum*).

With a magnifier look for the lid which fits like a cover over the capsule. Find an old capsule which has shed its cover. The lid over the opening at the top is called the *operculum*. Draw it.

What may be seen surrounding the opening after the lid is removed? Breathe on the top of the capsule and quickly look at it with a magnifier. What occurs? The ring of teeth within the mouth of the capsule is called the *peristome*. How do the teeth behave when moist breath touches them? Give reasons for this. Draw. Of what use to a moss plant is this property of the peristome?

Note. — A moss leaf mounted in a drop of water under the microscope is an excellent object for showing chloroplasts.

211. MOSSES

Object. — *To learn what is meant by alternation of generations.*

Method. — Prepare a shallow flowerpot by filling it with soil to within an inch of the top. Dampen it and set it in a saucer of water so as to prevent drying out. Crush several moss capsules on a piece of paper to obtain the spores and sow them by blowing them over the soil in the pot. Cover it with a glass plate and set it away in a shady place.

When the spores have begun to germinate, examine a portion with the magnifier and later with a low power.

1. The protonemata will show numerous branching filaments. Look for *buds*, which will develop into leafy moss plants. Look for *rhizoids*, which are delicate hairlike structures used as roots. With a higher power look for chloroplasts. *Draw a protonema, showing all structures.*

2. Procure specimens of Funaria, Mnium, or Polytrichum in spring for use fresh, and preserve some in formalin, for later in the year.

Remove a rosette from the tip of one plant and place on a glass slip in a drop of water. With a pair of needles, tear it apart and examine with a low power.

Look for flask-shaped organs, which will usually be found floating in the water. These are the archegonia. Look for club-shaped structures in like manner. These are antheridia.

If a drop of weak caustic potash be allowed to flow under the cover glass, the archegonia will become clearer and the egg can be seen within.

If fresh antheridia be crushed and examined with a high

power, the sperms will be seen swimming about in the water.

Make drawings of all structures seen.

Reproduction in Mosses. — Mosses admirably illustrate the phenomena of *alternation of generations.*

The life history of a moss plant may be described as follows: 1. Spores are produced in the capsule of the plant studied in the preceding exercise. The capsule, together with its stalk (seta) is known as a sporophyte (spore plant). Spores falling upon favorable soil germinate, forming a delicate green plant called a *protonema,* which is made up of numerous branching filaments.

2. The protonemata have numerous hairlike structures resembling root hairs, which are called *rhizoids.* They also bear tiny buds which ultimately develop into *leafy moss plants.*

3. The leafy moss plant is known as a *gametophyte,* because it bears the sex organs, or *gametes,* carefully tucked away among the minute leaves forming the rosette at its top.

The male gamete is called an *antheridium.* The female gamete is called an *archegonium.*

The sexes may be on the same plant (monœcious) or upon different plants (diœcious) as among flowering plants.

Within the archegonia are *egg cells* and within the antheridia are numerous *sperms.* Fertilization is effected by union of a sperm with an egg cell, whereupon the latter proceeds to develop into the spore-bearing plant (sporophyte), thus making the life cycle complete. The sporophyte remains attached to the leafy moss plant and grows upon it like a parasite. Thus we have two alternating generations; namely, the gametophyte which produces the eggs and sperms, and the sporophyte, producing non-sexual spores.

212. A FERN

Object. — *To learn the characteristics of the spore-bearing stage of a fern.*

Apparatus. — Any common fern (one of the shield ferns (aspidium) is preferable), and a magnifier.

Method. — Study the plant as a whole, making out its roots, its underground stem (rhizoma), its leaves (fronds), and their peculiar manner of folding or rolling in the bud (circinate).

FIG. 110. — A fern plant. *a*, fronds and rootstock; *b*, fertile pinna; *s*, *s*, sori; *c*, cross section of a stipe, showing ends of the fibrovascular bundles; *d*, a cluster of sporangia, magnified; *e*, a single sporangium still more magnified, shedding its spores.

Examine the frond and make out its venation. How does the veining differ from that of leaves hitherto observed? Note the parts into which the frond is divided (primæ, etc.). Is the frond alike on both sides? If so, it is a sterile frond. Find a frond which has dots on the under side. These are called *sori*. Describe the sori, their size, color, and arrangement on the frond. Make a sketch of a portion of the frond, indicating as many

of these details as can be made out with help of the magnifier.

Some ferns have the sori covered with a shield (indusium), others are naked, and still others are covered by a fold of the frond. (Compare maidenhair and brake.)

With a needle, lift an indusium and find the spore cases (sporangia) underneath. Have they stalks? Draw a sorus covered by the indusium, also one having the indusium removed. Draw one sporangium.

Spores. — Lay a mature fern frond upon a sheet of white paper. Cover it with another paper until it is perfectly dry. Then lift the frond and a considerable quantity of black or brown dust will be found where the fern frond has been lying.

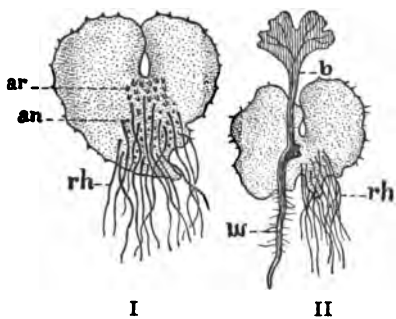


FIG. 111. — Prothallium of a common fern (*Aspidium*). I, under surface, showing rhizoids, *rh*, antheridia, *an*, and archegonia, *ar*; II, under surface of an older gametophyte, showing rhizoids, *rh*, and young sporophyte, with root, *w*, and leaf, *b*.

Suggestion — The following ferns are very common. As each has a peculiar manner of bearing its sporangia, it is suggested that as many of them be studied as possible.

Onoclea, the sensitive fern, shows marked differences between the sterile and fertile fronds. It also has an intermediate form which is interesting.

Pteris, the brake, covers its sporangia with a fold of the frond like a hem.

Osmundas show three interesting modifications of fertile fronds. In the *cinnamon* fern there is a beautiful brown fertile frond. The *royal* fern has the fertile portion only

at the tip of the frond. There is another species, *Clayton's*, in which the fertile portion is near the middle of a huge sterile frond.

The ostrich fern, the walking leaf, the moonwort, are very characteristic. The maidenhair, *adiantum*, conceals the spores under the overlapping tips of the delicate leaves.

Aspidium, the shield fern, is easily recognized by the curious shields called indusia which cover the sporangia.

Gather as many different kinds of ferns as possible. Bring them together and learn their names. Every one should be able to recognize at least ten species of ferns. Reference to almost any standard text will enable one to learn to identify them.

213. A FERN

Object. — *To propagate ferns from spores.*

Prepare a large glass jar or Wardian case with about an inch of ashes or gravel on the bottom. Above this put a layer of rich wood soil and sprinkle it with water. Let it stand for a day or so to allow the soil to settle and drain off all superfluous water.

Now crumble some fertile fern fronds fresh from the plant over the jar so that there will be an abundant supply of spores to fall upon the prepared soil.

Cover the jar with a plate of glass and stand it in a shady spot where the temperature is proper for germination.

After from two to four weeks, small green bodies resembling delicate leaves will be found here and there upon the surface. These are the beginnings of ferns (prothallia).

When the prothallia are about a quarter inch in diameter, remove one, place it in a dish of water, and examine it.

What is its shape? Examine both sides. Has it roots

(rhizoids)? If so, where are they found? If your magnifier is very strong, you may be able to find minute protuberances on the under side. They are the sex organs of the fern plant.

After a few days longer, observe the prothallia again, and you will doubtless find tiny fern plants growing from them.

Where do these come from? Is there any advantage in the shape of a prothallium? If so, what?

Ferns like mosses show the phenomena of alternate generations. The sporophyte stage is the familiar fern plant. The gametophyte stage is seen in the prothallium with its archegonia and antheridia.

Note to Teachers. — In propagating ferns from spores, water the soil well to begin with, before the spores are sowed. Keep it covered with a plate of glass to prevent drying out. Do not water the culture again until it is desired to have fertilization take place. Prothallia will live indefinitely, and no fertilization occurs if there is no water in which the sperms can swim. After watering, the embryo fern plants will soon appear.

214. YEAST AND FERMENTATION

Object. — *To study the growth of yeast.*

Method. — Prepare two wide-mouth bottles. Fill each one about half full of water in which a small quantity of sugar has been dissolved.

Add to one bottle a small piece of yeast cake dissolved in water or a teaspoonful of liquid yeast. Let the other bottle remain as a control. Place both preparations in a warm place and allow them to stand for several hours.

What change, if any, takes place in each bottle? How do the contents of the first bottle differ from that of the second? To what must this difference be due? Note the smell, if any. Plunge a lighted stick into each jar and test

the gas above the liquids. How do they differ? Test with limewater by holding a glass rod on which hangs a drop of limewater.

What gas is given off by substances in which yeast is working? Repeat this Experiment using a small portion of bread dough.

215. YEAST

Object. — *To prove that carbon dioxide is given off in fermentation.*

Apparatus. — Test tubes, limewater, perforated stopper, and bent tube as shown in Figure 112.

Method. — Fit up an apparatus like that shown in Figure 112, filling one tube half full of the molasses preparation mentioned in the preceding Experiment. Fill the other tube with limewater and let the gas from the fermentating sirup pass through the limewater. Result?

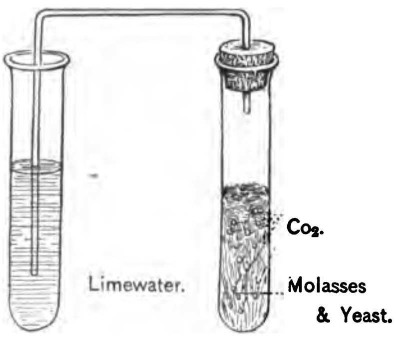


FIG. 112.

Conclusion. — What does this show as to the gas given off when fermentation takes place?

Note. — Alcohol also is produced in this experiment and remains dissolved in the solution. Its presence can be detected by the odor, and it can be obtained if the substance is distilled. It is hardly advisable, however, to take the time to distill it although that is an interesting and instructive experiment.

Cider and fresh fruit juices may be substituted for molasses.

216. YEAST

Object. — *To determine conditions favorable to the growth of yeast.*

Method. — Prepare three bottles of sugar and water. Add yeast to each and place one in a *cold* place, another in a *warm* room, and the third on a radiator or other *hot* surface.

After several hours examine the three preparations and note results. What conclusion can be drawn at this point?

Now put all three bottles in a warm place and let them stand for another period. Result? What conditions are most favorable to yeast? How are these conditions observed in bread making? In brewing?

217. YEAST

Object. — *To discover the effect of extreme heat on yeast.*

Method. — Prepare three bottles of sugar and water and treat them as follows: After adding the yeast, heat one bottle scalding hot and then set it away for observation. Place the other two in a warm place until fermentation has begun, then heat the second bottle scalding hot. Allow all three bottles to stand for several hours longer. Then compare the results.

Conclusion. — Why does fermentation not continue after bread is baked? Give reason for your answer.

218. YEAST

Object. — *To find out what substance is necessary to yeast.*

Method. — Prepare bottles containing various substances other than sugar and add yeast as before. Do all substances ferment? Try starch paste, salt solution, fruit juice, flour,

rice, etc. Try some of these which have been sweetened and others plain. What may be inferred from these experiments?

From the foregoing Experiments, answer the following questions: —

Under what conditions does yeast develop? What effect has heat on the growth of the yeast plants? How does cold affect their growth? What is given off by these plants? On what substance does yeast feed? How may fermentation be stopped? How may it be hindered? What gas is produced by yeast? How do you account for the frothing of liquids containing yeast? What causes bread to rise? Will fermentation go on forever? If not, why not? Reasons for your answer. How long will fermentation continue?

219. YEAST (optional)

Object. — *To observe the form of yeast plants and their manner of reproduction.*

Method. — Mount a drop of liquid yeast or any substance in which yeast is growing and cover it with a cover glass. Examine it first with a low power and then with a higher power objective. Note the oval cells of yeast. Are all of equal size? Find cells which are joined. Look for cells producing smaller cells (buds). Sometimes several cells can be distinguished, forming chains or colonies. What is the color of these plants? Can they manufacture starch? Give reasons for your answer.

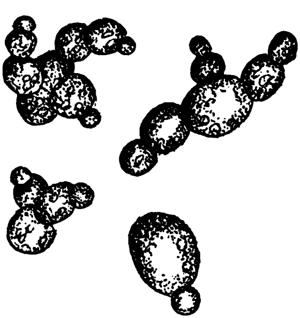


Fig. 113. — Yeast plants.

220. YEAST

Object. — *To demonstrate the result of desiccation on yeast.*

Method. — Mix a little fresh yeast with some corn meal and a small quantity of sugar until it has the consistency of stiff dough.

Spread it on a board to dry. When it is thoroughly dried, put it away in a jar and keep it dry.

After a week or two, dissolve a little in a vessel of warm sweetened water and keep it in a warm place. Does it show signs of fermentation? How do you account for this? Does drying kill or merely check the development of yeast plants?

Try other portions after a longer interval. Result? Can yeast be kept indefinitely in a dry state?

Why does the grocer sell dry yeast of any age, but only fresh moist yeast?

Bacteria

Bacteria are very minute plants, so minute that it requires the highest power of the microscope to reveal them. Indeed they cannot be seen clearly even with the microscope without the use of various staining reagents.

As individual plants, therefore, they are not to be considered in a work of this character. They may, however, be studied in a broad way, since it is possible to cultivate them in various nutrient solutions, where they develop so rapidly as to form spots resembling mold, which are colonies of bacteria.

Culture Medium. — A standard culture medium is made out of the following:—

Agar, 5 g.
Beef extract, 5 g.
Peptone, 5 g.
Common salt, 5 g.
Water, 500 cc.

Directions. — Dissolve the beef, peptone, and salt in water and neutralize with sodium carbonate if necessary.

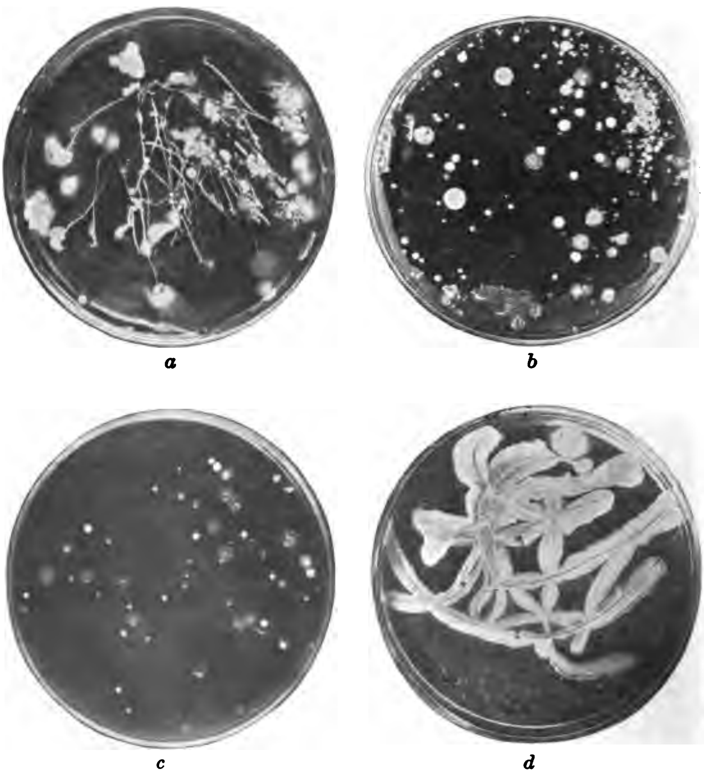


Fig. 114. — Bacteria. *a*, from drinking cup; *b*, from lunch room; *c*, from schoolroom; *d*, on hairs.

Dissolve the agar in boiling water and add the first solution, stirring constantly until they are thoroughly blended.

Test with litmus and neutralize again if necessary with sodium carbonate. Add water to make up to 500 cc. Boil the solution and filter it hot through absorbent cotton. Pour it into sterilized Petri dishes or test tubes as desired.

Sterilizing. — (*a*) Dishes, needles, tubes, etc., are sterilized by being boiled for fifteen minutes in water in which washing soda has been dissolved, and then being thoroughly rinsed in boiling or very hot water. They should be dried in an oven or over a Bunsen burner or alcohol lamp flame.

(*b*) Needles, platinum wires, etc., may be sterilized by being held in a flame until red-hot.

(*c*) Absorbent cotton, used for the plugs in test-tube cultures, is sterilized by being placed in an oven and heated until it is on the verge of scorching. When the cotton begins to assume a brownish hue, it should be removed and placed in a sterilized fruit jar ready for use.

221. BACTERIA

Object. — *To prove the presence of bacteria in the air.*

Apparatus. — Petri dishes and a culture medium.

Method. — Having sterilized the Petri dishes, put a small quantity of the culture medium in each. There should be only enough to flow over the bottom of the Petri dish so as to leave a thin, even layer when the agar sets.

Cover the dishes to exclude dust and set them away until the material has become firm.

Examine the dishes and note the clear, transparent character of the culture medium.

Set apart one dish for a *control* and label it *A*. Then expose a second dish to the air for ten minutes. Close it and label it *B*. Set it aside with *A*, in a warm place where the thermometer reads 36° C.

Leave the preparations and examine them from day to day until spots appear on the surface of the culture medium.

Describe the color and any differences in appearance of these spots.

Look for spots on the control dish. What does this prove regarding the source of the spots?

Conclusion. — How can you explain the presence of the spots in the dish which was exposed if no spots appear in the control dish?

222. BACTERIA

Object. — *To demonstrate the fact that the air in some localities is richer than others in bacteria.*

Apparatus. — Same as in the preceding Experiment. Several Petri dishes will be required.

Method. — Prepare dishes as before, setting one away as a control. Then expose each of the remaining dishes for ten minutes in different places, such as the cellar, pantry, parlor, attic, and the street. Dishes may be exposed in different houses and in different parts of the city, as streets, parks, or public buildings.

Label each dish and bring all together with the control in a place where the temperature is 36° C. and again make observations from day to day.

Conclusion. — State what localities give most and what ones the fewest colonies of bacteria.

223. BACTERIA

Object. — *To prove the presence of bacteria in water.*

Apparatus. — Test tubes, culture medium, and sterilized cotton.

Method. — Fill two test tubes with the culture medium to about $\frac{1}{2}$ their depth. Pour into one about 10 cc. of drinking water and close the mouth of the tube with a plug of sterilized cotton.

Into the second tube, pour the same amount of water which has been boiled. Plug the second tube as before and place both preparations at a temperature of 36° C.

After several days, examine both tubes, making note of any differences in color, odor, and reaction on litmus. What effect has boiling upon the water used?

Suggestion. — In like manner, try different samples of water, such as that from wells, cisterns, streams, pools, ditches, etc.

224. BACTERIA

Object. — *To demonstrate the prevalence of bacteria.*

Method. — Make several cultures, using such things as tartar from the teeth, scrapings from the finger nails, phlegm, pus, saliva, etc.

Make cultures, using money, articles of clothing, door knobs, tool handles, and books as sources of bacteria.

Prepare Petri dish with sterilized culture medium and let a fly walk over the surface and leave it for several days. Touch a lead pencil which has been used to the agar in a Petri dish. What result?

Make two cultures of any sort of bacteria and add a drop of corrosive sublimate, formalin, carbolic acid, Platt's chlorides, or any other disinfectant to one of them. Label the cultures and set them away for observation. Result?

225. BACTERIA

Object. — *To demonstrate the relation between soil bacteria and the growth of plants.*

Apparatus. — Flowerpots, soil, clover seed or alfalfa.

Method. — Fill two flowerpots of medium size with soil. Rich soil dug from a field where clover is growing is the best for the purpose. Sift the soil to remove stones, roots, and other coarse matter.

Heat *one* flowerpot in an oven for an hour. This will sterilize the soil if the heating has been thorough.

Sterilize seeds of clover or alfalfa by rinsing them in a very dilute solution (2 per cent) of formalin and then rinse them in distilled or sterilized water.

Plant the sterilized seeds placing an equal number in each of the flowerpots.

The seeds will then be placed in exactly similar conditions with exception of the soil which in one flowerpot has been freed of bacteria, while the other has not been sterilized.

Place both pots under conditions favorable for growth and keep them so until the young plants have been growing for some time.

What difference is noticed in the two plants? Compare them as to height, vigor, number of leaves, and general appearance. Keep the plants growing if necessary for a month or six weeks before making the comparison. Remove both plants from the soil by turning the flowerpots over so that the roots will come out uninjured, and examine the exposed roots. Are they alike? If not, what differences are observable? Draw or make blueprints of the root of each plant.

Conclusion. — What may be inferred as the difference

between sterilized and unsterilized soil in supplying nourishment to plants?

Note. — If a sample of soil should contain harmful bacteria, sterilization would kill them and the soil would be better for the plant than unsterilized soil, for then the plant could absorb such mineral foods as might be present without interference from bacterial foes.

Leguminous plants, such as clover, alfalfa, beans, peas, etc., usually have swellings upon their roots which are the home of bacteria. These organisms perform valuable work by absorbing nitrogen from the air, which they build up into nitrites and nitrates. In this way, plant foods are formed. The process is known as *fixation* of nitrogen, and such bacteria are called nitrifying bacteria.

Cells and Protoplasm

If the student refers to the various demonstrations with the microscope (Exs. 54, 91, 108, 109, 146, 147, 198, and 215), he will find that on close inspection all these plant structures

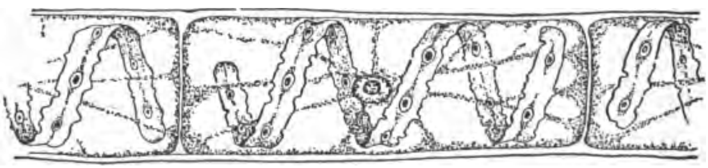


FIG. 115. — Spirogyra.

are built up of very small units called cells. In seeds of the horse bean (*Vicia faba*) the cells can be plainly seen with the naked eye or with a simple magnifier.

If sketches of all the different forms of cells are made and compared, they will be found to have three points of similarity; namely, a very delicate sac or membrane, the *cell wall*, containing a clear transparent fluid, the *protoplasm*, and suspended somewhere within it, a tiny mass of slightly denser material, the *nucleus*.

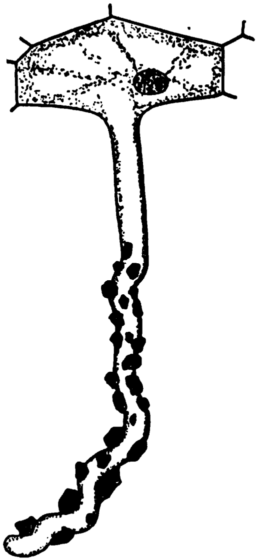


FIG. 116.—Root hair of wheat.

Root hairs seen on young roots are cells of slender tubular shape. Palisade cells in the leaf are oblong and contain many chloroplasts or green corpuscles which carry on the work of starch making. The delicate threads of pond scum or spirogyra are made up of short cylindrical cells whose chlorophyll grains are arranged in very beautiful spiral threads. Guard cells of the stomata occur in pairs and are half round or kidney-shaped, and the cells of leaf epidermis are very various in outline. Compare also the sections of monocotyl and dicotyl stems, and various other cell forms will be seen.

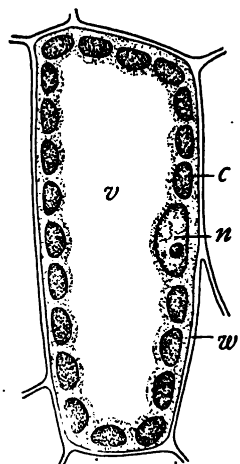


FIG. 117.—Diagram of a mesophyl cell of a leaf; *c*, chloroplast; *n*, nucleus; *v*, vacuole; *w*, cell wall.

But no matter what the form may be, all cells studied and most vegetable cells will be found to agree in having the three parts named — wall, protoplasm, and nucleus.

Mount thin sections of plant tissues, root hairs, pollen grains, moss leaves, etc., in water under cover glasses and study them with low power; and when the thinness of the section will permit, examine them also with a higher power.

The nuclei will not always be seen in this way, but a drop of methyl green or iodine solution run under the cover glass will often stain the nucleus so as to make it plainly visible.

If young onion root tips are prepared and properly sectioned, the wonderful process of cell division known as mitosis will be seen. This, however, requires careful preparation of the mounts. Prepared sections are preferable.

226. PROTOPLASM

Object. — *To demonstrate the living contents of a cell.*

Apparatus. — Microscope, slips, cover glasses, and a flower of tradescantia.

Method. — Mount a fresh stamen in a drop of water and examine the hairs which are found upon the filaments.

Note the cells of which these hairs are made. Watch for some time until the eye is accustomed to the field. The contents of the cell will be seen to be circulating inside the walls. This slowly streaming fluid is the protoplasm. It is alive. Does the protoplasm move about the nucleus or does the nucleus also circulate in the stream?

227. PROTOPLASM

Object. — *To contrast the behavior of living with dead cells.*

Apparatus. — A red beet root, knife, beakers, and water.

Method. — Slice the root in thin pieces and place one or two of them in boiling water for five minutes to kill the protoplasm. Now put raw slices in one beaker of water and the cooked slices in another. Let them stand for ten minutes and note result.

How do you explain the difference?

228. PROTOPLASM

Object. — *To demonstrate automatic movement in plants.* (See also Exs. 155–161).

Apparatus. — Any twining plant of rapid growth, such as a hop morning-glory, or cinnamon vine, a cardboard disk, and an upright support.

Method. — Select a plant about six or eight inches high, and examine it. Does it show any signs of coiling? Bring it into contact with a slender upright cord or rod. Does it respond? If so, how? When it begins to coil, note the direction in which it turns. Can it be made to revolve in the opposite direction?

When it reaches the top of the support, leave it and watch its revolutions.

Over the end of the stem slip a circular disk of cardboard and fasten it to the support. Note the revolutions of the stem and indicate the different positions on the disk. Note the time of each position. Does the plant move in a definite period of rotation or not?

Does the motion increase or diminish at night? Does watering produce any change in rate of rotation?

Protoplasm. — The living substance of which plants and animals are made is called *protoplasm,* a word which means first form. It differs from all other substances in being *alive.* Chemically it consists of varying quantities of carbon, nitrogen, hydrogen, oxygen, phosphorus, sulphur, and traces of several other elements, and resembles a protein. But no chemist can analyze it, for in so doing it must necessarily be killed, and then it is protoplasm no longer.

The fact that it is *alive* gives to protoplasm several distinctive properties.

1. *Selective absorption* is the ability to take or reject those things which are needed. This is shown in the fact that two plants, as corn and tobacco, growing side by side in the same soil, will take up only those substances needed by each. Again, the leaf takes into its stomata all the substances of the air, but selects only the carbon dioxide for making starch and enough oxygen for respiration, giving back what it rejects into the atmosphere.

2. *Metabolism* is the power of protoplasm to utilize the absorbed materials and give off wastes.

3. *Assimilation* is the making of more protoplasm out of the substances which have been selected and changed (1 and 2).

4. *Growth.* Increase in size and weight naturally results from the increase in the amount of protoplasm (1, 2, and 3).

5. *Excretion.* This is the ability to throw off waste matters. This is seen in the excretion of water in transpiration, in excretion of oxygen in photosynthesis, and in the excretion of carbon dioxide in respiration of all living things.

6. *Reproduction* is shown in the power of plants and animals to propagate their kind.

7. *Automatic movement.* Protoplasm is the only form of matter which can move of itself. It can contract, expand, and move about from place to place. This is seen in the streaming of sap, in the change in position of leaves, and in the motions of animals from one place to another.

8. *Irritability.* This is the power to respond to outside influences called stimuli. The behavior of tendrils, the phenomena of hydrotropism, heliotropism, and geotropism, all illustrate this property.

Cells. — A unit of protoplasm is called a cell or protoplast. It is the smallest particle of protoplasm that can live alone,

It is the physiological unit of the plant or animal body. The plant or animal is the sum total of its cells. Every cell consists of protoplasm and has a nucleus. Vegetable cells usually also have a cell wall which is composed of a substance called *cellulose,* secreted by the protoplasm of the cell. (See Ex. 147.)

Every living cell can select, change, assimilate, grow, excrete, and perform all other functions of protoplasm.

They can reproduce other cells by a process of division which can be seen in sections of young root tips and by budding, as we saw in yeast.

Growth of plants is increase in size due to an increase in the number of cells.

Every living thing, whether plant or animal, begins its existence as a single cell known as an egg. By a series of cell divisions followed by corresponding growth the embryo is at length developed and all later growth is due to increase in number of the cells.

Adaptation of parts to function applies to cells as well as to plant organs. Thus are developed all manner of cell forms, such as root hairs, guard cells, palisade cells, piths, pollen, wood, etc., each adapted to its own peculiar work.

Tissues. — When cells are engaged in doing the same sort of work, they assume similar form and appearance. Such a collection of similar cells is called a *tissue.* Thus we have seen epidermis, cortex, and fibrovascular tissues in the root. In the stem were pith, bark, bast, spiral, and many other tissues. In the leaf were epidermis, palisade, spongy parenchyma, etc. In like manner, animals have bony, muscular, nervous, fatty, and many other tissues.

Organs. — An *organ* is a tissue or collection of tissues

operating in harmony to do a special work. This work is the *function* of an organ.

The root is an organ whose function is to absorb plant foods, to anchor the plant to the soil, and to store food. The stem is an organ whose function is to carry sap up and down from root to leaf and back, to bring the leaves into the light, and to store food. The leaf is an organ having many important functions.

The entire plant or animal body, being composed of organs, is known as an *organism;* and hence the substances which come from plants and animals are distinguished as *organic* substances.

A LIST OF APPARATUS AND REAGENTS REQUIRED IN MAKING THE EXPERIMENTS

I. APPARATUS

Battery jars.
Beakers.
Bell jar.
Blotting paper.
Bottles —
- wide-mouth.
- narrow-mouth.
- flat.

Corks (assorted sizes).
Cork cutter.
Cotton batting.
Cover glasses.

File.
Flask for gas generator.
Flowerpots.
Forceps.
Funnels.

Glass tubing.
Glass plate.

Ignition tube.
Insect pins.

Jars —
- fruit.
- tall.
- graduated.

Knife.

Litmus cubes.
Litmus paper.
Lamp.

Magnifiers.
Microscope.

Needles.

Petri dishes.
Platinum wire.
Platinum foil.
Pins.

Rubber bands.
Rubber stoppers.
Rubber tissue.
Rubber tubing.
Ruler.

Sand.
Sawdust.
Scalpels.
Sealing wax.

Thermometers.
Thistle tubes.

Thread.

U-tubes.

Watch glasses.
Whetstone.
Wire.

II. REAGENTS

Absorbent cotton.
Acids.
  sulphuric.
  nitric.
  hydrochloric.
Agar.
Alcanna solution.
Alcohol, eth.
Alcohol, meth.
Ammonia.
Aniline dyes.

Benedict's sol.
Biuret reagent.

Calcium nitrate.
Carbolic acid.
Carbon (charcoal).
Carbon (lampblack).
Cobaltic chloride.
Collodion.
Copper sulphate.

Diastase.

Eosin.
Ether.

Fehling's sol.
Formaldehyde.

Gelatin.
Glycerine.

Iodine.
Iron filings.

Lime.
Limewater.
Litmus cubes.
Litmus paper.

Magnesium sulphate.
Marble.
Mercuric oxide.
Mercury.
Methyl green.
Millon's reagent.

Phenolphthalein.
Phosphorus.
Potassium bichromate.
Potassium hydroxide.
Potassium iodine.
Potassium nitrate.
Potassium neutral phosphate.
Potassium permanganate.

Sodium carbonate.
Sodium chloride.
Sodium hydroxide.
Sodium nitrate.

Soudan III.

Zinc.